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Economic Development in the Massachusetts Life Sciences Cluster: Shared Prosperity or a Big Tradeoff?

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ECONOMIC DEVELOPMENT IN THE MASSACHUSETTS LIFE SCIENCES

CLUSTER: SHARED PROSPERITY OR A BIG TRADEOFF?

A Dissertation Presented

by

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ABSTRACT

ECONOMIC DEVELOPMENT IN THE MASSACHUSETTS LIFE SCIENCES CLUSTER: SHARED PROSPERITY OR A BIG TRADEOFF?

December 2014

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Policies aimed at economic development can be judged by two criteria: efficiency and equity. -Policies that result in both greater efficiency and greater equity lead to shared economic prosperity for a region. The innovation economy includes some of the fastest growing industries which generate new wealth in the U.S. Within this context, the life sciences industry has been a prime target for economic development for individual states. This case study examines the economic development agenda in the Massachusetts life sciences industry and whether these efforts result in both sustaining competitive advantage (i.e., continuous innovation that improves productivity and product and service quality) and supporting greater equity – particularly equality of opportunity and a fair distribution of outcomes. In addition to examining how economic development supports

sustained competitive advantage, the study focuses on the extent to which equity goals are defined, implemented, and realized by employers and stakeholders in this fast growing sector.

This case study design employs both quantitative and qualitative methods, between 2000 and 2010. I find that the life sciences industries in Massachusetts have sustained competitive advantage with growth and concentration intensifying in the second half of the decade. Growth in the life sciences has benefited the highest skilled workers, but left many others behind. Industry concentration in downstream operations (e.g., manufacturing and clinical trials), which is thought to benefit mid-skilled workers, has not been realized in Massachusetts. However, there is some evidence that economic benefits are spreading. Growth has concentrated not only in the Boston-Cambridge core, but also in the Worcester I-495 region. Although women and minorities have been underrepresented in the innovation economy, they have had greater access to employment opportunities in the life sciences when compared to other high tech sectors.

In the interest of supporting equity goals in economic development, possible policy solutions are numerous. Growth in the life sciences sector results in increased state tax revenues. This increase in revenue is more than sufficient to cover existing economic development efforts and might also cover initiatives in the local services sector and increase initiatives that address workforce diversity.

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CHAPTER 1

INTRODUCTION

This research seeks to discover whether the economic development agenda in the Massachusetts life sciences industries can simultaneously ensure efficient outcomes for industry while encouraging more equitable outcomes for different communities or groups of workers within the state. Specifically, efficiency is defined as sustained competitive advantage for Massachusetts' biotechnology and other life sciences sectors. Sustained competitive advantage is defined in turn as continuous innovation to improve productivity and product or service quality. Equity is defined as a fair distribution of economic benefits. For example, greater equity might be achieved by improving access to employment opportunities over time for groups and communities that have not been immediate beneficiaries of the innovation economy. This case study takes a close look at economic development policies and stakeholders in the life sciences industries. It examines how economic development supports sustained competitive advantage and the extent to which equity goals are defined, implemented, and realized by employers and stakeholders in this fast growing sector. Ultimately, the case study seeks to discover whether these economic development efforts result in a tradeoff between sustained competitive advantage and equitable outcomes or if they contribute to shared economic prosperity for residents of the state.

The relationship between efficiency and equity in public policy

In the field of economics, the concept of Pareto efficiency is used to understand how a competitive market allocates goods and services. In a competitive market, consumers use their income (which is derived from selling labor and other factor inputs such as land and capital) to purchase the goods and services they want. Prices for goods and services "arise" based on the costs of factor inputs to firms, their profit maximization goals, and the willingness of consumers to pay. The result is Pareto efficient if the allocation of goods and services is such that no one person could be made better off without making someone else worse off (Weimer & Vining, 1999). This idea that competitive markets are efficient is often the basis for advocating for minimal government intervention in the economy. However, efficiency is not the only thing we value as a society. Equity is an example of another such value. The market economy alone does not ensure an equitable distribution of benefits across all members of society. Economic inequality produced by market forces contributes to social exclusion, erodes democratic processes and civic life, and impedes a broad conception of economic prosperity. In many contexts, public policy has been used to bolster efficiency and steer or redistribute the economic benefits of capitalism in more equitable ways (Okun, 1975).

In fact, public policy can be judged by these two criteria: its effect on efficiency and its contribution to equity. With these criteria in mind, there are four possible outcomes for society. These logical policy outcomes are: a) more equitable and more efficient; b) less equitable, but more efficient; c) more equitable, but less efficient; and d) less equitable and less efficient. Policies with an a) outcome (more equitable and more efficient) are highly desirable and most likely to lead to shared economic prosperity. Outcomes b) and c) are the result of a tradeoff -- a policy outcome that sacrifices one value for another. Arthur Okun (1975) argued most policies that are intended to help direct market outcomes are the result of a tradeoff that society makes between efficiency and equity. Therefore, society must make decisions (e.g., through the policy making process) about how much efficiency will be sacrificed for equity and vice versa. Lastly, policy outcome d) is not desirable by either criterion and should be avoided.

Efficiency and equity in the innovation economy

In the context of economic development and the "innovation economy," how might one consider policy options with respect to efficiency and equity? The innovation economy has been defined as the high-tech industry sectors or clusters that are generating new wealth driven by rapid technological advancements and globalization (see, for example, Massachusetts Technology Collaborative, 2014). The innovation economy contains some of the most prosperous industries and receives a wealth of private investment and public support. For example, there are 11 key sectors in Massachusetts including financial services, software and communication services, and biopharma and medical devices. Efficiency in the innovation economy can be thought of as Pareto efficiency, but there are a number of other market outcomes that stem from efficiency that are important as well. Increased productivity -- getting more out of a given set of inputs, such as achieving higher total shipments of a good given a certain employment level -- is one such outcome. Innovation is another outcome. The development of new or improved products, services, or processes (e.g., increases in patents, research and development spending, and venture capital) are indicators of innovation (Massachusetts Technology Collaborative, 2014). Overall, one outcome incorporates all of this – sustained competitive advantage. Sustained competitive advantage might refer to a specific region (such as a state) where continuous innovation improves productivity and product or service quality (Bluestone, Stevenson & Williams, 2008).

Following the logic of market efficiency described above, we do not expect sustained competitive advantage in the innovation economy by itself to ensure an equitable distribution of economic gains across a region or among a set of individuals. In fact, industry research in the U.S. has pointed to the high skilled nature of employment in the innovation economy and its concentration in a few key regions, especially California and Massachusetts (Batelle Technology Partnership Practice, 2010). But greater equity might be achieved through public policy. For example, public policies that encourage firms in the innovation economy to locate in underutilized regions or help connect public education to key sectors in the innovation economy will support more equitable outcomes and greater access to the economic benefits provided by these sectors.

Currently, within the U.S. innovation economy, state (or regional) economic development projects use a variety of policy tools to improve or sustain the competitive position of particular industry sectors. These projects target high-technology, high-skilled industries. These projects seek to foster innovation and entrepreneurship in order to attain or sustain competitive advantage and regional economic prosperity. Well-designed regional or state development projects are expected to result in an increase in export base jobs (i.e., jobs that produce products and services that attract buyers from outside the region), venture capital investment and educational attainment; thereby, employing more people in well-paying jobs and increasing tax receipts (Bluestone *et al.*, 2008; Clark & Christopherson, 2009; Cooke, 2001, 2004; Porter, 2003a, 2003b).

Competitive advantage for a region is subject to decay over time. Therefore, sustaining competitive advantage and ensuring regional prosperity from an economic development perspective requires continually injecting resources into a region's firms and infrastructure. Economic development projects require a long-term perspective in order to support continual innovation and resource development (e.g., human resources and public infrastructure). Economic development in the innovation economy includes promoting and supporting research and development and encouraging entrepreneurial risk, but also includes public and private investments that work to sustain competitive advantage over time (Bluestone et al., 2008).

The Massachusetts biotechnology and life sciences sector is an example where a specific region is engaged in economic development to support sustained competitive advantage in the innovation economy. In Massachusetts, this sustained competitive advantage in biotechnology and other life sciences has primarily relied on growing research and development activities (Sum et al., 2007b). The state is now well known for and highly ranked in this area. In the past decade, sustained competitive advantage has also meant growth in "downstream" activities (e.g., manufacturing and clinical research) and improved coordination between the system of higher education, demand for labor, and industry training needs. Economic development policies have focused on supporting these industry activities. At the same time, industry research has shown that the expansion of the life sciences primarily benefits highly skilled workers and specific regions in the state. What is less well understood with respect to economic development in the life sciences is the extent to which the value of equity is represented in these policies. Further, more should be uncovered to understand equitable outcomes in this sector. For example, how has workforce diversity grown as life sciences employment has expanded and to what extent have low or moderately skilled workers been incorporated into the life sciences sector?

Research questions

The development and use of biotechnology and other life sciences applications in Massachusetts, particularly in the field of human health, serves as a critical case example of sustained competitive advantage supported by state economic development efforts in the innovation economy. Massachusetts is the leading state ranked by the Biopharma Innovation Index (Milken Institute, 2004). Biotechnology and other life sciences industries have been expanding in Massachusetts for many decades. The state's trade association, (Massachusetts Biotechnology Council, 2010) reports that between 2000 and 2009, employment in Massachusetts's biotechnology sector grew 60% and that biopharmaceutical manufacturing grew 25%.

Since about 2005, there have been a number of new economic development initiatives launched to support the life sciences in Massachusetts. Economic development activity picked up momentum following the announcement that Bristol Meyers Squibb would be locating its largest biologics facility in Devens, Massachusetts. The announcement of the new facility reinforced to state officials and industry stakeholders that Massachusetts was able to attract substantial production activity and there were viable locations in the state for biomanufacturing (Heuser, 2006).

Examples of private economic development initiatives have included the New England Biomanufacturing Collaborative's apprenticeship program (est. 2004), the Massachusetts Life Science Education Consortium convened by MassBio's Education Foundation (est. 2009) and MassBio's BioReady campaign (est. 2008). Other efforts have been made through formal policies, such as the establishment of tax credit and workforce programs through the Massachusetts Life Sciences Center. The Massachusetts Life Sciences Center was founded in 2008 under the Massachusetts Life Sciences Act. Overall, this has resulted in a package of policy tools and private initiatives to help meet the workforce and local infrastructure needs of life sciences employers and maintain Massachusetts's competitive position in the industry. While the primary policy goal has been to improve the state's competitive position, secondary goals have included meeting the needs of the workforce across a range of skills and throughout the state. This case study asks whether the package of economic development tools has benefited the state's workforce by providing good jobs at various skill levels and growing employment opportunities across different sub-regions within the state. The research questions for this case study follow.

1. The first research question seeks to confirm that Massachusetts is sustaining its competitive advantage in the life sciences and that the sector is expanding its downstream operations. How can sustained competitive advantage in the Massachusetts life sciences industry be measured, and have downstream operations (e.g., manufacturing and clinical trials) expanded?
   a) Has Massachusetts sustained competitive advantage in the life sciences since 2000 and, if so, how does it compare to other high tech sectors in the innovation economy?
   b) To what extent has sustained competitive advantage been achieved in the "downstream" activities of the life sciences (e.g., in manufacturing and clinical trials)?
2. Massachusetts has a strong and growing industry cluster in the state with many important assets, particularly its university and health systems and its access to venture capital. This growth has contributed to the stock of good jobs. Jobs in the life sciences are highly paid even at entry level and are well benefited. The second research question is concerned with the distribution of that job growth. Has the growth in good jobs in the core life sciences industry been accompanied by more equitable outcomes and, in particular, have the number of life sciences jobs grown in

regions outside of the metropolitan core, and has workforce diversity expanded along with industry growth?

a) Has sustained competitive advantage in the Massachusetts life sciences been accompanied by an increase in earnings inequality?

b) How have jobs grown across different regions in the state and how does this growth align with different economic development investments?

c) How, if at all, has workforce diversity (e.g., in skill level, sex, race, ethnicity, veteran status, and nativity) expanded in the life sciences?

d) How have "downstream" activities contributed to the industry mix across the state and the occupational structure within the industry?

e) To what extent has the Massachusetts core life sciences industry contributed to more equitable outcomes with respect to sub-state regional growth and workforce diversity when compared to the rest of the innovation economy?

3. Given what is learned about sustained competitive advantage and equitable outcomes from answering research questions 1 and 2, do stakeholders view the balance between the two as a tradeoff or as an opportunity for shared prosperity? The third research question seeks to shed light on how equity goals and interests are incorporated into the economic development agenda. In concrete terms, how do stakeholders (e.g., development intermediaries, educators, and employers) view equity and efficiency as it relates to their role in supporting and growing the life sciences industry in Massachusetts?

a) What are stakeholder views on industry outlook and regional competitiveness, particularly with respect to “downstream” operations?

b) How do stakeholders view the objectives of economic development policies and initiatives with respect to efficiency and equity?

c) How have employers engaged in regional economic development initiatives and what have they gained?

Summary

This study aims to understand whether economic development efforts contribute to both efficiency and equity, how the policies address these criteria, and the degree to which equitable and efficient outcomes are evident in the Massachusetts life sciences sector. In the context of the innovation economy, efficiency is defined as sustained competitive advantage or the continuous innovation of processes, products, and services. Equity is defined as increased access to economic benefits and a fairer distribution of economic outcomes. Here, economic development policy is evaluated based on these two criteria to show the extent to which it is possible to develop and implement a policy agenda that includes both in the interest of shared economic prosperity.

The innovation economy has become a prime target for state economic development efforts. In Massachusetts, the highly ranked life sciences industries provide a critical case example of how public and private stakeholders have invested in initiatives to help the region (the state) sustain competitive advantage in this sector. The research asks whether the range of economic development initiatives and the efforts of many stakeholders have resulted not just in sustaining competitive advantage for the region, but whether that state's workforce has benefited from the provision of good jobs at various skill levels across the state.

CHAPTER 2

LITERATURE REVIEW

This literature review starts by highlighting the work of Arthur Okun (1975) as he framed the debate between equity and efficiency as a tradeoff; arguing that policies often require decision makers to weigh economic efficiency against economic equity. Okun's book, *Equality and Efficiency: The Big Tradeoff*, and his ideas have been influential in mainstream politics since in the 1970s. However, tradeoff thinking is not necessary in all policy domains. There are other ways to understand the relationship between efficiency and equity, particularly through the social bargains framework provided by Robert Kuttner (1984) and, more recently, in the editorial writings of Paul Krugman (2014a, 2014b, and 2014c). While Krugman's emphasis is on an economy operating below full employment, a situation in which it is more likely that government spending to stimulate the economy will be both efficient (making use of idle capacity) and more equitable (benefiting unemployed workers), Kuttner's social bargains framework argues that policy can be devised under conditions that set efficiency and equity as complementary. Compared to other countries, the U.S. has been challenged to do that. Kuttner attributes this to weak labor market institutions that are not conducive to strong social bargains.

Second, this literature review defines efficiency. For this case study, efficiency needs to be understood in terms of its relevance to the innovation economy. The innovation economy is made up of some of the fastest growing industries which are producing new wealth in the economy. This sector of the economy does not just rely on market dynamics to flourish, but also requires a strong public sector that contributes to the development of technology, workforce skills, and infrastructure. Instead of defining efficiency in traditional terms, such as Pareto efficiency as defined in the introduction, this study has defined efficiency as sustained competitive advantage. Relying on Michael Porter's (1990) work on competitive advantage and industry clusters, we understand that growth and prosperity in the innovation economy is accompanied by two important conditions. As industry concentrates in particular regions, it benefits from positive externalities that include knowledge spillovers and firm linkages, which facilitate learning and development across the industry. Also, this industry concentration contributes to the export base as more products and services are demanded from consumers outside of the region.

Next, the life sciences industries in Massachusetts are an example in the innovation economy where industry and government are both key stakeholders in economic outcomes. One of the main avenues for government to participate in the economic success of the life sciences industries is through economic development. In the past 10 years, state governments have learned about cluster strategies. Industry clusters form as firms locate in proximity of rivals. These agglomeration economies benefit from positive externalities, like established labor pools and common infrastructure. In turn, state governments have used a variety of tools to support their growth. One of the most popular tools has been tax credits, but governments have developed other demand-side strategies, including low interest loans. Supporting the demand side of a regional economy means helping meet the needs of existing and new businesses; helping businesses control costs or helping fund small companies and startups. Governments have also focused on supply-side strategies in their regional economies through educational institutions and infrastructure development. Supply-side strategies support workforce development, technology parks, and utility needs.

As a condition of government support (such as tax credits), industry is encouraged to engage in these projects. Employers make choices regarding the nature of their contribution to economic development projects, and the literature on labor markets and industrial relations helps us understand the employer’s position. Overall, policies studied here seek to engage employers, but do not require their participation. Economic development efforts have in general treated employers as customers with the hope of engaging them in education and training and job creation initiatives.

Ultimately this literature review helps to further explain the criteria of efficiency and equity in judging policy and how this applies to economic development in the innovation economy. Further, it helps define important terms used in the study and helps focus the research questions.

Equity and efficiency according to Okun

Standard neoclassical economic theory states that a market economy, when left to operate on its own, makes efficient decisions on the use of resources. However, the market economy does not necessarily ensure an equitable distribution of benefits across all members of society (Weimer and Vining, 1999). If left unattended, economic inequality produced by market forces contributes to social exclusion and erodes democratic processes and civic life. In many contexts, public policy has been used to steer or redistribute the economic benefits of capitalism in a more equitable way. For the purpose of evaluating public policy (as described by Andersen (1979) this research focuses on the two criteria of efficiency and equity. According to Arthur Okun (1975), the use of policy to help direct market outcomes usually results in a tradeoff between efficiency and equity. In other words, society must make decisions on how much efficiency will be sacrificed in the interest of equitable outcomes.

Okun argues that at times the market can undermine our rights and contribute to income inequality. Despite this, the market – or the American capitalist system – is the most efficient way we know to organize the production of material goods. This system favors innovation, flexibility, and entrepreneurship. However, in this system we tolerate a significant amount of inequality. Okun defines efficiency as “getting the most out of a given input (p. 2)” and posits that the production of goods and services match with what consumers want to buy. He defines greater equity as families having “a maintainable standard of living,” which implies “lesser . . . disparities of income and wealth than currently exist (p. 3).”

Today, there is cause for concern with respect to income inequality. Research has documented growth in inequality in the past 30 years for the U.S. Inequality is driven by increasing income for top earners (McCall & Percheski, 2010). The tax and transfer system has had little effect on this trend (Heathcote, Perri, & Giovanni, 2010). Overall, this is expected to impede intergenerational mobility, reduce consumption, impede economic growth, and negatively impact morale and productivity (Krueger, 2012). Further, the job market has become increasingly polarized into high-skilled/high-wage and low-skilled/low-wage jobs (Autor, 2011).

For Okun, equality of opportunity is related to both equity and efficiency. Equality of opportunity means ensuring a level playing field with respect to access. It also means making the most of a given set of inputs. For example, jobs in science and engineering have historically favored white men. Improving educational programs, developing mentors with diverse backgrounds, and changing hiring practices to benefit women and minorities increases access to jobs for underrepresented groups (Hill, Corbett & St. Rose, 2010). At the same time, these types of efforts broaden the available pool of labor, making hiring more efficient. Increasing equality of opportunity helps make the race more fair while at the same time improving efficiency. However, in the context of great inequality, achieving equality of opportunity can be difficult. If that is the case, the tradeoff between equity and efficiency is likely to remain. In these instances, the pursuit of greater economic equity requires difficult choices.

Okun (1975) devises a thought experiment called “the leaky bucket” and uses the tax and transfer system as an example. The leaky bucket experiment helps demonstrate how decision makers might consider a tradeoff between efficiency and equity. The bucket redistributes income. It collects taxes from the rich and delivers transfers to the poor. In the transfer process the bucket leaks due to administrative costs and disincentives to work, save, and invest. Decision makers can choose how much leakage is tolerable for society and evaluate different policy alternatives. In other words, there is a cost associated with equity. However, these are short-term costs. Recent research suggests that over the long term, sustaining economic growth requires a reduction in inequality. Other authors have argued that it is possible to reconcile efficiency and equity and not treat them as a tradeoff (Berg & Ostry, 2011).

Given Okun's work, Kuttner (1984) argues that the field of economics has put too much emphasis on the tradeoff between equity and efficiency and that more often than not policy can reconcile the two. Reconciling equity and efficiency is a political choice that depends on institutional forms and the distribution of power. Instead of focusing on a tradeoff or technical economic arguments, Kuttner uses the terminology of social bargains. Such a focus emphasizes the political nature of setting policies that address both equity and efficiency.

Kuttner provides a wealth of examples, both historic and contemporary, of how social bargains are used to reach compromises between equity and efficiency. However, the weak labor market institutions in the U.S. inhibit social bargaining. While Okun argued that our existing institutions were sufficient, Kuttner comparatively demonstrates that the U.S. lacks institutional forms conducive to social bargains, mostly because we have a weak labor movement (e.g., fragmented and declining unions). In Northern

Europe and some western European countries the labor movement has a stronger political presence. There, the labor movement is associated with a political party (e.g., the Social Democratic party), it is highly centralized, and it works on broad egalitarian goals (e.g., full employment). In contrast, unions in the U.S. have been rapidly declining, even more so since Kuttner's writing. They are fragmented and often on the defensive. Changes for the Wisconsin teachers' unions are a recent case in point. Every local union now has to bargain separately with each school district and is forced to choose between either layoffs or decreased benefits and increased workloads. Collective bargaining for the Wisconsin teachers' unions has been clearly posed as a tradeoff between efficient school budgets and protection of the progress made to compensate teachers fairly by the Republican governor (Greenhouse, 2014).

Weak institutions in the U.S. have resulted in tradeoff thinking, even when there is plenty of examples elsewhere that social bargains can be struck. However, weak institutions lack the political status needed to negotiate for efficient and egalitarian outcomes. Kuttner (1984) describes the U.S. employment services as focused on transferring benefits to the unemployed. Federal and state employment services have not been a strong force in intervening in job training and re-training and job placement; thereby, not contributing to a decrease in unemployment. Whereas the Swedish model of active labor market policy achieves its goal of full employment by offering wage subsidies and job placement for dislocated and unemployed workers. The low level of intervention in the U.S. does not lead to egalitarian outcomes – and not necessarily efficient outcomes either. Greater equity results from political power to negotiate social bargains. Much of this political power is stripped away from our labor market institutions.

More recently, Paul Krugman (2014a, 2014b, & 2014c) has been writing about how inequality hampers economic growth and efforts to increase equity appear to be benign. New evidence provided by the International Monetary Fund supports these assertions, as do recent experiments at the state level. Over the long run, Krugman argues that in order to support sustained economic growth, inequality needs to be reduced. He also explains in the short run that individual states can make progress. For example, California instituted recent tax hikes that have been accompanied by positive outcomes such as job growth, an increase in the number of people with health insurance, and a state budget surplus.

Equity and efficiency in the innovation economy

The innovation economy is a term used to identify the industry sectors in the economy that produce new wealth,[1] compete globally, and contribute to the development and use of new technologies (Massachusetts Technology Collaborative, 2014). The innovation economy includes some of the most prosperous industries, like biotechnology and the life sciences, as well as other high-tech industries and clusters. Although Arthur Okun (1975) was not specifically concerned with the innovation economy, his work provides a starting ground for operationalizing equity and efficiency within a particular policy domain. There are a few ways to apply Okun's theory to the innovation economy.

[1] New wealth is primarily generated by increasing access to the stock market. Successful development and use of technology is an important avenue through which companies and individuals get access to the stock market (The Economist, 2001).

First, increasing new wealth alone does not suffice in achieving a fair distribution of economic benefits. Second, increasing equality of opportunity in the innovation economy is also efficient. Greater equality of opportunity means improved access to jobs for a wide range of people and regions, but also means a larger labor pool to draw upon. Okun argues that greater equality of opportunity does not result in a tradeoff with efficiency. Therefore, so long as new wealth is being generated, society should continue to strive for equality of opportunity. Third, in the pursuit of equitable outcomes through a distributive mechanism (other than the market), society must make decisions on how much efficiency can be sacrificed for the sake of equity. If tradeoffs do exist, the "leaky bucket" thought experiment can help us do this; however if efficiency and equity are complimentary and institutional power is sufficient Kuttner 's (1984) social bargains framework should be deployed.

Sustained competitive advantage as efficiency in the innovation economy

Michael Porter defined competitive advantage in his 1985 book *Competitive Advantage*. Firms gain a competitive advantage either through differentiation or low-cost strategies. In order to differentiate products and services or control costs of production, firms can deploy new technologies, make changes to address new buyer needs, take advantage of opportunities in new industry segments, keep costs low, and address new government regulations. Competitive advantage can erode over time. Sustaining that advantage is a dynamic (not static) process. Therefore to sustain competitive advantage firms must continue to innovate in order to either improve the efficiency of their production or to develop higher quality products. Evaluating a firm or an industry in this regard requires looking at how new products and processes are improved over time and how they increase productivity. Firms sustain competitive advantage over time by becoming more sophisticated. They rely on a highly skilled workforce, they attract investment, they behave strategically, given their position in the value chain, and engage in constant improvement (Porter, 1990). Ultimately, economic prosperity for a region depends on firms' ability to stay ahead and sustain its advantage. This includes "constant research and development, innovation, and creation of new resources (Bluestone *et al.*, 2008, p. 180)."

Additionally, a region's firms can benefit from agglomeration economies by capturing the effects of externalities. Industry clusters in Porter's terms develop as firms choose to locate in geographic proximity of rivals. Industry clustering allows firms to benefit from knowledge spillovers, established labor pools and infrastructure. In this context, sustained competitive advantage through differentiation requires high-quality resources. These resources include labor, natural resources, knowledge, capital (i.e., financial backing), and common infrastructure. The quality of these resources depends on linkages and connections across the cluster that involve the interworking of business, government and educational institutions (Bluestone et al., 2008).

Competitive advantage also relates to export base theory (Bluestone et al., 2008). Export base theory focuses on the demand side of a region's economy. The demand side includes new and existing firms. In export base theory for a state (or other region), a product is an export if it attracts buyers from other regions. In other words, the demand for particular products and services reaches beyond the state's boundary. The location quotient is one way to measure whether an industry is part of the export base within a region (such as a state). The location quotient can be used to measure the concentration of an industry's employment in a state relative to the U.S. as a whole. Location quotients greater than one represent an export base industry for the state. Although the measure is less than precise because it does not measure actual amounts of product or service that are purchased by a consumer outside of the region, it does indicate whether a state has a greater proportion of industrial activity and can generate income by selling products or services to other states (or countries) (Bluestone et al., 2008). Jobs in an export base industry stand in contrast to local services jobs. For example, a dry cleaner is likely not selling its services to consumers outside of a particular locality; whereas high tech services are likely to attract consumers outside of a local region. Export base jobs are important to understanding prosperity for the state. When export base jobs get created, there is often a multiplier effect in that jobs are also created in the local service economy. A multiplier effect occurs when an increase in spending results in an increase in income and consumption that is greater than the original amount spent (Bluestone et al., 2008).

For example, Sum *et al.* (2007a) calculated a number of multiplier effects for the life sciences industries in Massachusetts. They showed that a one million dollar increase in was associated with an increase of seven new jobs in research and development and nearly two jobs for manufacturing in the life sciences. Additionally, this increase in sales volume was also associated with new jobs in the local service sector. A one million dollar increase in sales in the life sciences industries is associated with one new job each for

Accommodation and Food Services, Retail, and Administrative/Waste Management services.

The life sciences constitute an important export base industry for Massachusetts. Such regional industries generate income by selling goods and services to other regions, which is the primary way a region generates wealth. Life sciences jobs also have a strong multiplier effect. Competitive advantage, as it applies to Massachusetts life sciences industries, means that when firms locate in Massachusetts they have a good chance of differentiating themselves through innovation because of the high skills available in the labor force, as well as other cluster assets (or externalities). Sustaining competitive advantage means continually innovating in a region that is known to provide access to unique technologies, reputations, and skills (e.g., knowledge spillovers).

Sustaining competitive advantage in an export base industry is a common rationale for economic development policy. However, since a region's exports will change over time, it is important for regions to emphasize the supply side of the region's economy. A focus on the supply side is not specific to an industry per se but seeks a longer term perspective on improving skills of the labor force and improving infrastructure, thereby providing a region with the resources it needs to continually innovate and create products and services that add to the export base (Bluestone et al., 2008).

Sustained competitive advantage and equity

There is a significant amount of research on industrial agglomeration, the geographical concentration of industries in the life sciences and other high tech industries that stems from the above ideas about regional development and competitiveness. Most recently, this research has identified the industrial, institutional, and social components that support clusters and innovation systems. The geographic concentration of high technology development and commercialization is primarily attributed to strong academic anchors, sufficient venture capital, the continuous injection of new entrants or startups, and the presence of multinational enterprises (Cooke, 2001, 2004). Historical trajectories, geographies, institutions, and the quality of networks shape the social context within which economic activity occurs and these factors give rise to variation in clusters across different regions (Christopherson & Clark, 2007; De Laurentis, 2009; Gertler, 2009; Pinto, 2009; Powell et al., 2010; Saxenian, 1994; Youtie & Shapira, 2008).

Importantly, policies and strategies that support spatial agglomeration and industry clusters also imply intra-regional inequities. For example, as industry activity continues to concentrate in certain areas of a state or in a particular metropolitan area other areas within the region are left out. Research is mixed with regard to whether or not the growth of a cluster within a region produces growth overall for that region (Chetty *et al.*, 2013). In the context of sustained competitive advantage, industry agglomeration, and economic development, equity comes to the fore in some of the literature. A few examples follow.

Clark and Christopherson (2009) provide an overview of two types of regionalism that have evolved in the U.S. First, investment regionalism mirrors the economic development efforts seen in the Massachusetts life sciences cluster. Investment regionalism focuses on clusters and regional innovation systems. Governments invest in tax subsidies as a way to grow more jobs. These efforts are influenced by businesses in the region and are good for development and sustained competitive advantage. However, they are associated with growing more inequality because there is little consideration of the distributive outcomes. In other words, issues of equity across a region are not addressed while investment regionalism emphasizes innovation and entrepreneurship. This stands in contrast to distributive regionalism.

Distributive regionalism projects, as defined by Clark and Christopherson (2009), originate from community-based coalitions and organizations. This definition is primarily concerned about access, opportunity, and equity. Clark and Christopherson argue that regional projects focused on high tech sectors could become more progressive projects by focusing on the labor market as a whole, not just the high-skilled jobs. Focusing on the labor market as a whole helps define the region and acknowledge issues of equity and sustainability. Regional economic development in the innovation economy often fails to consider jobs beyond high tech export base industries.

Bluestone and Stevenson (2000) document "a triple revolution" in Greater Boston from the 1970s thru the 1990s. Boston has undergone formative changes demographically, industrially, and spatially. Authors find that these changes in the metro area have impacted attitudes on race and ethnicity; decisions on where to live, and, importantly, who benefits from economic growth. At the end of the 20th century, Greater Boston was well positioned economically. Industry had shifted toward a “mind-based” economy (e.g., high technology). Additionally, the economy was boosted by a high concentration of higher education institutions and healthcare services. The labor force was supported by an influx of new immigrants. And unlike many other cities, Boston has fared well with respect to concentrated settlement in the city, including low income neighborhoods. Relative to other older cities in the Northeast and the Midwest, it has maintained population in its city core even while the suburbs have grown. Despite these successes, Boston still suffers from residential segregation, persistent poverty and high cost real estate. By 2000, Boston was in need of improvements in the public school system; finding ways to make higher education more affordable to a larger group of residents; and increasing the stock of affordable housing. Boston is also challenged with respect to inequality. Income inequality has continued to grow. As the region experiences high growth and a successful economy, these benefits have failed to improve conditions for low-income workers and families.

Lastly, Porter applies his theory of competitive advantage to the “inner city” or low-income neighborhoods in the city core (1995). The inner city has some disadvantages. Including a lack of useable land and higher real estate costs when compared to the suburbs; real and perceived safety problems; lack of infrastructure that connects the inner city to the regional economy; unskilled workforce; low access to capital and debt; and anti-business attitudes. Porter argues that these disadvantages should be framed as an economic problem, not a social problem. For example, disadvantages can be overcome by looking for economic solutions as opposed to social services. The role of government is to deal with the realities in the inner city market place and engage business around real profitability. Porter also argues that the inner city has a real set of advantages and opportunities. Inner cities have a substantial workforce that is under-employed – providing a source of unused labor. The inner city is located near downtown business districts. Businesses in the inner city that serve those business districts have a locational advantage. There is also unmet demand for services and products in the inner city neighborhoods. Businesses with well-considered plans to meet consumer demand will be profitable. It is also possible to connect the inner city businesses within regional clusters through economic development efforts. In addition to considering the effects of sustained competitive advantage on equity, it is important to remember equity in a broader economic context. While sustained competitive advantage may contribute to inequality within a region, there are other forces at play that contribute to inequality. Rapid increases in inequality since the late 1970s have been explained by Davidson (2013). In the 1950s, through unionization and social security, workers were able to gain benefits from economic growth. However, since 1978 the U.S. government has focused on deregulation, ignoring unionized labor, and resulting in a weakening welfare state. In these ways, government has contributed to growing inequality. Additionally, the increase in college educated workers coupled with technology development and management bias that favors higher educated workers have resulted in what is termed "skill-biased technical change." For the last 20 years, research has implicated the Internet and computers as culprits of inequality, meaning that higher skilled workers have benefited from information technology while lower skilled workers have been left behind.

Economic development in the U.S. innovation economy

Economic development is a broad policy domain that includes public and private efforts to improve economic conditions in a particular place and often for particular industries. These efforts focus on encouraging business development and expansion within a region. The end goal of economic development is to grow good jobs for a region's residents and increase the tax base for a state or municipality. In other words, economic development is concerned with economic prosperity (although not necessarily *shared* economic prosperity) for a region – not just with the competitive position of firms (Bartik, 2003; Bluestone et al., 2008).

National, state and local governments promote and invest in regions with strong biotechnology and other life sciences clusters in order to sustain competitive advantage within these regions as industry activity continues to expand. The life sciences industry cluster provides a good case example for learning how governments can best support industry and cluster growth in the innovation economy and contribute to the creation of new wealth for a region (Cooke, 2001, 2004; R. W. DeVol; Perry; Ki, Junghoon; Bedroussian, Armen; Koepp, Rob, 2004; Porter, 2003b). As an example, research conducted in Massachusetts has found that biopharmaceutical jobs provide higher pay and better benefit coverage than the average job in the state and provide a greater contribution to the state and local tax base on a per job basis (Khatiwada *et al.*, 2007).

Therefore, the life sciences industries have been an attractive target for economic development efforts.

States have increasingly focused economic development policy on the innovation economy – high tech sectors within a regional economy that are heavily driven by entrepreneurship and technological change. Not every state is as well positioned as Massachusetts or California to compete in these industries; however most states are investing in R&D capacity, supporting early stage capital needs, and offering R&D tax credits (Batelle Technology Partnership Practice, 2010). Economic development in high tech sectors, life sciences included, requires substantial investments most often beyond the scale and scope of a municipality (Bartik, 2003). State level efforts may have local or regional foci as well as spillover effects to neighboring states, but the role of the state in the U.S. innovation economy is important. Although, it may be true that industries cluster or concentrate in regions that cross state geopolitical boundaries (B. T. McCann & Folta, 2008), state's power to enact and support relevant policy tools far exceeds that of municipalities. A state level effort also reduces the need for localities to compete with each other in attracting high technology business, so long as the state effort is concerned with the distribution of development across the area.

In the U.S., state economic development agendas focused on the innovation economy have relied on the construct of industry clusters (Porter, 1990). Governments and industry stakeholders have been big proponents of cluster strategies and regional efforts. Research and practice literature has advanced ideas about clusters, networks, competitive advantage and regional innovation systems using geographic and governance frames that support industry agglomeration, innovation and entrepreneurship. In fact, Michael Porter himself, as an academic consultant, has helped shape the competitive agenda for Massachusetts life sciences cluster (Porter, 2003b). Most recently, states have developed new strategies that extend beyond just offering tax credits for large firms and incentives to attract new business. States have learned that most new job growth happens when existing businesses expand. This has resulted in a focus on smaller companies and entrepreneurs as well as small start-ups. New trends in state economic development include developing intermediaries to support business expansion and bringing together industry and community colleges to address industry-specific training needs and skill gaps (Sparks, 2013).

Most of the research reviewed on economic development in the innovation economy supports supply-side government intervention. In general, policies focus on growth, not equity. The process of supplying industry with economic supports for growth detracts from other spending programs like welfare assistance – possibly sacrificing equity for efficiency. For example, Bartik (1996) found that cutting welfare spending to support economic development programs lifted the income for the top 4/5ths of a state, but left the bottom quintile out. Current economic development programs may not be doing all they could do with respect to distributing the benefits of new wealth more broadly across the state. For Massachusetts and other states, research and practice literature remains unclear on how this industry benefits the state’s residents broadly, including how jobs are being created, where are they located and why and who ultimately gets to work in them.

Economic development policy tools

Overall, economic development policy tools seek to lower costs for firms and leverage private investments to produce beneficial outcomes for employers, workers, and residents. In the context of state economic development and high tech sectors, there is a range of policy tools, usually implemented in conjunction with each other as a package of different strategies. Each policy tool is more or less effective and briefly described in APPENDIX A.

Importantly, states have engaged in significant supply-side investments related to education and infrastructure. Although research supports the use of supply-side initiatives, states also engage in a number of demand-side strategies which provide financial assistance to firms (Bluestone et al., 2008). A brief description of economic development strategies distinguished as either supply-side or demand side follows.

Supply-side strategies:

- ***Education and training*** programs and subsidies are intended to improve the quality of the labor force and increase productivity for firms. Community colleges have played a large role in corporate education and training programs. Subsidies help firms cover the cost of training. With respect to business retention,[2] economic development stakeholders accumulate information on business needs through surveys, visits, and business extension services (e.g., technology consultations which lead to productivity gains) that help identify education and

[2] Business retention is important. Existing businesses develop ties to their location and constitute about 85 percent of new plant openings in any given region (Bartik, 2003).

training needs. However, for firms considering new locations, decisions are often based on the pre-existing labor force. The evidence is mixed on how public spending on education and training impacts employment (Bartik, 2003; Bluestone et al., 2008).

- ***Infrastructure*** investments include transportation and utility improvements and enhancements and the development of industrial and technology parks. Business makes location decisions at least to some degree on the presence of high quality infrastructure. Additionally, some industries – like the life sciences – have particular infrastructure needs (e.g., waste water and exhaust systems). Infrastructure projects are often capital intensive and should be evaluated with respect to opportunity costs (Bluestone et al., 2008).

Demand-side strategies

- ***Purchasing and lobbying*** strategies increase government demand for products and services at the state and local level, as well as lobbying the federal government to contract with entities in a specific region (Bluestone et al., 2008).
- ***Financing*** strategies help reduce the cost of capital and include grants, loans, and venture capital arrangements that help companies manage risk. Financing strategies through public intermediaries are desirable at a particular point in development. For example, the Massachusetts Life Sciences Center provides loans and grants for early stage research and startup companies. However, these kinds of financial resources (e.g., revolving loan programs, loan guarantees for higher risk companies, and providing incubator space and resources) produce

minimal benefit with respect to employment growth. They may offer some social benefits if they are focused on women and minority owned business (Bartik, 2003; Bluestone et al., 2008).

- ***Tax incentives*** are common in most states. They are often granted in exchange for job creation commitments. Studies show that tax credits related to training and hiring disadvantaged job seekers are not efficient or effective. Most research does not find that state and local taxes have a big impact on business location decisions; they are expensive and have modest results. Tax incentives can have an impact for a particular firm, at a particular point in time (Bartik, 2003; Bluestone et al., 2008).
- ***Regulation*** and industrial policies vary at the state and local level, particularly zoning laws. Also, industry associations engage in lobbying (at multiple levels of government), not just to increase government demand, but to work on policy issues that impact the industry and its business environment (Bartik, 2003; Massachusetts Biotechnology Council, 2008).

In addition, ***information and coordination*** services are of increasing importance in economic development, particularly with respect to the labor market, business services, and negotiating regulations (Bartik, 2003). Different organizations position themselves as intermediaries that work to improve the quality of information and networks for an industry or region. Improved information and coordination affects both the demand and supply side efforts. For example, Benner and other authors (Benner, 2002; Benner *et al.*,

2003) provide a framework on labor market intermediation. This special group of intermediaries helps reduce transaction costs for workers and employers by coordinating labor market activity; they help build business and social networks by acting as third-parties in the labor market; and help reduce risk brought about by economic volatility. As another example, MassBio operates as an intermediary for a purchasing consortium, business service referrals, funding development, and streamlining regulations (Massachusetts Biotechnology Council, 2008).

Labor markets and industrial relations – the impact of internal firm job structure on labor market outcomes

Especially, in the absence of unions, employers have significant say so on how they structure jobs, where they locate them, and how they recruit their workforce. From a policy perspective, economic development has conceded most of the decision making power about jobs to employers. Turning to the literature on industrial organization helps address some of the limits in the economic development research and policy literature. Economic development policy has had some influence on employer decision making by coaxing firms towards desirable outcomes. For example, in considering jobs, economic development initiatives have increasingly linked to training strategies, but these initiatives do not require employers to participate. Most often, employers engage (if at all) at particular points in time when the strategy meets their immediate needs. Further, even the most engaged employers in a particular training project are not required to hire training program graduates (Conway, 2011). Economic development policy has a limited reach, particularly with respect to the labor market and the structure and conditions of jobs. Therefore, the field of industrial relations helps us understand more about the manner in which firms organize themselves, the structure of their operations, and the impact of competitive strategies on labor market outcomes.

In *The Second Industrial Divide,* Piore and Sabel (1984) discuss the importance of a "craft alternative" in organizing the workforce as our economy shifts away from mass production towards flexible specialization. Among many things, the authors provide an argument for why workers and employers benefit from the establishment of associations based on occupations or technologies. The shift to flexible specialization means workforce training will meet particular challenges. As the front line workforce (production workers) is increasingly required to shift across jobs and collaborate with the architects of technology to solve problems and execute operations, it thus requires much broader training. "…[T]he more broadly skilled the workforce, the greater the danger that firms will economize on training costs." Employers will seek workers already trained at another firm's expense or they worry that workers they train will move onto another firm. This has been a visible dynamic in the life sciences, especially in manufacturing.

Other authors (Benner, 2002; Herzenberg *et al.*, 1998; Osterman *et al.*, 2001) continued to stress the importance of worker associations in the flexible economy; arguing that these associations should be defined by occupations and technology. Public policy and worker associations are our best mechanisms for addressing career development, cross-firm career paths, skill standards, training institutions and job referral systems by working with groups of firms (not just a single employer). In the view of the authors above, labor market policies need to shift away from the firm as the central institution and consider industrial and occupational clusters as the main locus of economic activity. These policies should be concerned with the learning process and not just training workers for discrete skills. Workforce policies need to build communities of practice and social networks alleviate the onus now often put on individual workers to navigate complex labor markets. Importantly, labor market efficiencies are not just achieved by the market alone, but also depend on the social context within which economic activity is embedded.

Employers make choices in how they hire and fill open positions. In recent years, all kinds of employers have reported that they cannot find qualified candidates, which is often termed a skills gap, and has resulted in employers blaming the educational system for not producing work-ready graduates. Yet, at least some of what employers want is “work” skills, not “academic” skills (Capelli, 2013). So far, employers have conceded very little in trying to address these challenges. Their HR departments have declined, they do not reconsider how they screen and hire new recruits, they do not offer new ways to structure jobs, and they do not offer to raise wages. Instead, online screening and hiring has increased, employers are using overly detailed criteria that weed out otherwise qualified job applicants. Job descriptions have become too narrowly defined as employers search for the ideal “plug-and-play” candidate. For many firms, finding the ideal candidate means being able to minimize training costs (Cappelli, 2013; Popp, 2013). For now, workforce and economic development policy has focused on the needs of specific employers who engage in the system. Policy concedes control of labor inputs, wages, number and type of jobs, and the structure of work to employers. Policy emphasizes engaging employers as customers in providing workforce services without interfering with their ability to compete (Giloth, 2004).

A policy shift that focused more on industrial relations would recognize that workers move across firms. Workers interact with other firms just through their interactions with customers and suppliers alone. Further, most skills are not firm specific, but general and workers move jobs more frequently, worksites contain workers with multiple employers, and managers make decisions that have effects across entire supply chains (Benner, 2002). This shift would focus more on employers, challenge the misconception that labor market efficiency is guided by employers alone, and build new employment standards through policy and practice (Osterman & Shulman, 2011).

Conclusion

Standard definitions of efficiency emphasize that the market will adjust as conditions change and, if left unfettered, will result in producing the most output given a set of inputs and will provide what consumers want to buy. However, efficiency in the context of the innovation economy is defined as sustained competitive advantage. Sustained competitive advantage means continuously innovating to improve productivity and/or product and service quality.

Okun’s definition of economic equity is useful when thinking broadly. He defined equity as implying lesser disparities in income across households and families than already exists. However, with respect to regional development projects, intra-regional equity is defined as a fair distribution of the economic benefits that result from increased growth. Equality of opportunity, with respect to individuals, is having access to jobs or other economic benefits regardless of gender, race, class or other characteristics. With respect to sub-state regions, it is termed as having access to state and industry supported development projects regardless of intra-regional location.

The combination of both economic growth and economic equity results in shared prosperity for the region or state. In this case study, shared prosperity is the result of increasing wealth accompanied by decreasing inequality. The extent to which economic development projects produce shared prosperity depends on policies and practices that regard greater equity as a desirable and relevant goal, not just growth. The extent to which equity is addressed by a regional development goal will depend on decision makers as they consider solutions to a tradeoff between greater spatial agglomeration and industry concentrations within the region and greater equity of opportunity and the distribution of outcomes. Additionally, through a social bargains framework, stakeholders may develop new ways to incorporate equity as a goal through collaborations.

As biotechnology and life sciences industries have grown and flourished in Massachusetts and as the public sector has become increasingly involved in the economic success of this sector, it has become increasingly important to justify this growth as benefiting the state as a whole. One way to do that is to create jobs and economic opportunity that are accessible to residents in a variety of manners. For example, creating blue collar jobs in manufacturing that are located in the central, southern and western areas of the state would benefit the moderately skilled worker and help breathe new life into those sub-state regions. This requires that stakeholders and decision makers think outside the “growth box” and pay attention to equality of opportunity and the distribution of economic gains. The research presented here seeks to illuminate how equity considerations are factored into economic development policies and the extent to which these policies contribute to shared prosperity.

CHAPTER 3

CASE STUDY CONTEXT

Context is crucial. This study examines the conditions under which biotechnology and life sciences companies have developed within the New England region. Contextual factors considered in this case study include types of relevant stakeholders, targeted policy efforts (especially since 2005), historical developments in the industry, and changes in the state economic development climate. The context is helpful in understanding the regional trajectory of the industry, the different kinds of actors that help shape it, and the potential influence of economic development activity. Further, the context provides a basis for using time series analytics when examining case study evidence. This section on context is presented in two parts: first is a discussion on stakeholders and second a chronological description of relevant policy and industry events.

Targeted stakeholders – Employers, development intermediaries, and education and training providers

The life sciences cluster in Massachusetts encompasses a league of stakeholders, especially in light of the university and hospital systems, the scientific community, and the management and entrepreneurial networks. Many of these stakeholders were documented by the UMass Donahue Institute in the Life Sciences Talent Initiative (UMass Donahue Institute, 2008). This case study targets a subsection of these stakeholders: those related to workforce development and the expansion of downstream industry activities across the state. This includes large employers, contract research organizations, and contract manufacturing; development intermediaries focused on workforce programs or sub-state regional efforts; and education and training providers – namely community colleges.

In the past decade, there has been a tremendous amount of economic and business development activity targeting life sciences companies in Massachusetts. This case study focuses on policies and initiatives that address workforce issues, regional development around the state, and downstream operations. These policies and initiatives, -- the product of significant planning and research, -- were implemented primarily in the second half of the decade (2005-2010). Discussed briefly in this section the policies are described in detail in Appendix A: Descriptions of Selected Economic Development Policies and Initiatives in the Massachusetts Life Sciences Industries.

Large employers, contract research organizations, and contract manufacturers

There has been a shift (in Massachusetts as well as in other states) in thinking about the life sciences workforce: Regional competitiveness depends on more than the presence of high-skilled workers. Mid-skilled workers -- those who possess the necessary technical skills to support biologics production and laboratory services in downstream activities – are also crucial (Holzer & Lerman, 2007; UMass Donahue Institute, 2008). Large employers, contract research organizations, and contract manufacturers are the dominant firms driving downstream activity and they have an increasing demand for mid-skilled workers.

Not all of these Massachusetts employers engage in economic development and workforce and education initiatives. Employers who participate in such efforts are assumed to have an interest in collaborating on workforce and training investments. Their participation in regional investment strategies signals an economic perspective that collaboration with other parties across sectors is beneficial. To identify engaged employers, a search through the MassBio membership directory yielded a list of 301 companies that were operating in a biotechnology related field such as contract research or the development of drugs or medical devices. Of those 301 companies, 78 had engaged in at least one of the economic or workforce education initiatives outlined in the case study's timeline (described in a later section). All 78 companies were involved in more than one of the initiatives and about 20% were involved in four or more. Table 1 provides a list of the 15 employers most engaged in the state's economic development initiatives who need a range of skills across their workforce, including technical abilities of mid-skilled workers.

Table 1: MassBio member companies participating in four or more economic or workforce development initiatives

Company Name	Line of Business	Main Office Location	Employment (~approx.)
Abbott Laboratories	Drug Development	Worcester	750
AstraZeneca R&D Boston	Drug Development	Waltham	900
Biogen Idec	Drug Development	Cambridge	2,300
Bristol-Myers Squibb	Drug Development	Devens	320
Caliper Life Sciences, Inc.	Research Products & Instrumentation	Hopkinton	401
Charles River Laboratories	Contract Research & Manufacturing	Wilmington	970
Cubist Pharmaceuticals, Inc.	Drug Development	Lexington	626
EMD Serono, Inc.	Drug Development	Billerica	1,100
Genzyme Corporation	Drug Development	Cambridge	4,356
Microtest Laboratories, Inc.	Contract Research & Manufacturing	Agawam	85
Millennium: The Takeda Oncology Company	Drug Development	Cambridge	1,050
Millipore Corporation	Research Products & Instrumentation	Billerica	1,237
Organogenesis, Inc.	Drug Development	Canton	450
Shire Pharmaceuticals	Drug Development	Cambridge	1,500
Wolfe Laboratories, Inc.	Contract Research & Manufacturing	Watertown	25

Development intermediaries

Four development intermediaries were identified in Massachusetts as having a broad interest in supporting economic and workforce development in biotechnology and other life sciences sectors across the state. First, the Massachusetts Life Sciences Center (MLSC) is a quasi-public economic development organization concerned with capital investments and infrastructure, support for early research, job creation, and workforce development. The MLSC serves the life sciences industries, which includes biotechnology, but also major pharmaceuticals, medical devices, and diagnostics. Second, the Massachusetts Biotechnology Education Foundation (MBEF) is a nonprofit organization that provides education, training, and collaborative resources to biotechnology firms and employees as well as to the educational and workforce development systems. MBEF is affiliated with MassBio. Third, MassBio, the state's trade association, is also profiled in this section. MassBio, with over 600 members, is a strong state trade association, the oldest in the country. MassBio offers a number of services that align with and support MBEF's mission, including economic and business development services and announcements for open jobs in the industry. Lastly, the Massachusetts Life Sciences Collaborative was founded in 2006. The Collaborative is an industry and higher education partnership that works to support sector growth – including a specific initiative called the Biomanufacturing Roundtable.

The Massachusetts Life Sciences Center (MLSC)

In 2008, the Life Sciences Act was passed, which included the establishment of the Massachusetts Life Sciences Center (MLSC). MLSC was created as a quasi-public organization charged with implementing a 10-year, $1 billion economic development plan. Specific economic development programs provided through the MLSC include capital investments in infrastructure and tax incentives. Also, it offers programs related to workforce development, including the Internship Challenge and matching grants for training equipment and supplies for education programs. In addition, the MLSC provides accelerator loans for early stage companies and matching research grant programs. In 2011, the MLSC reported that its programs have invested $217 million in the life sciences industries, which created $754 million in matched private investment. MLSC programs have helped create 1,965 new jobs in the industry and provided numerous incentives to help retain business in Massachusetts. The Center has also created a corporate consortium attracting investments from multi-national enterprises like Johnson & Johnson and Sanofi Aventis (Massachusetts Biotechnology Education Foundation, 2008b; Massachusetts Life Sciences Center, 2009, 2010, 2011; Windham-Bannister & Mudawar, 2010).

The Massachusetts Biotechnology Education Foundation (MBEF)

The nonprofit Massachusetts Biotechnology Education Foundation (MBEF) was founded in 2001. Closely affiliated with MassBio, the state's trade association, MBEF's core mandate is to provide educational support for the biotechnology sector. Current initiatives include an extensive professional development program for the public K-12 education system (BioTeach), incumbent worker training, and industry leadership development. Although MassBio and its members are the key financial supporters of MBEF, the main rationale for developing it as an independent nonprofit organization is to assure its eligibility for external sources of funding (Hartford, 2010; Massachusetts Biotechnology Education Foundation, 2008a).

BioTeach is one of the longest running initiatives under MBEF. BioTeach provides professional development for teachers in the K-12 public school system. The program now includes 177 high schools of which 95 have a biotechnology elective for students. Since 2005, MBEF has helped supply training and equipment – a $3 million investment – to 177 public high schools which have exposed 500 science teachers and 26,000 students to industry related training. MBEF also provides incumbent worker training through its Learning Center. Courses offered through the Learning Center include project management, introduction to clinical research, a science course for non-science personnel, leadership development, presentation skills, and Current Good Manufacturing Practices (cGMP). Finally, MBEF operates a Resource Center that provides online tools and links students and professionals to speaking engagements, career panels, job shadowing, and company tours (Hartford, 2010; Massachusetts Biotechnology Education Foundation, 2009).

The Massachusetts Life Science Education Consortium (MLSEC) is led by the MBEF and is of particular interest to this study. MLSEC was formed in 2009 to help create linkages between the higher education system and industry employers. The consortium is composed of college and university presidents and industry leaders. MBEF is responsible for facilitating the consortium and providing administrative oversight, staff support, and organizational resources. In 2011, additional external funding for the consortium was provided by a two-year grant from The Boston Foundation. The initial focus of the consortium has been to develop industry-endorsed standards and core competencies for community college curriculums. In December 2010, eight community colleges received industry endorsements for their biotechnology related education and training programs. Silver endorsements went to programs offering curriculums that addressed a set of required competencies. The Gold went to programs that met the competencies but also provided internships (Hartford, 2010; Kriz, 2011).

The Massachusetts Biotechnology Council (MassBio)

The Massachusetts Biotechnology Council (MassBio) was established in 1985 and today has nearly 600 members. The association's membership includes dedicated biotechnology and other related companies, academic and research institutions, and organizations that offer business support services. MassBio functions as a connector in the biotechnology community and conducts public policy advocacy for its members. MassBio is the oldest state biotechnology trade association in the United States. The biotechnology related industry began growing in Massachusetts about a decade earlier than in any other state. Maintaining the state's competitive position and industry lead is the number one priority for MassBio. This includes retaining and building talent at all levels in the labor market (Abair, 2011; Massachusetts Biotechnology Council, 2008).

MassBio supports two staff lobbyists who work on legislative priorities, which include such important federal issues as stem cell research, healthcare reform, drug pricing, and funding from the National Institute of Health. The Economic Development department at MassBio has completed at least 60 community assessments for its BioReady campaign, which rates municipalities by their locational advantage in supporting biotechnology activity. BioReady community endorsements are based on a number of criteria mostly related to local municipal policies that support the development of biotech industry operations. MassBio has also launched a purchasing consortium which aggregates the buying power for regional companies and connects them with suppliers. In addition to sponsoring the Massachusetts Biotechnology Education Foundation, MassBio hosts a well-used and well-regarded industry job board for hiring employers and potential applicants (Abair, 2011; Massachusetts Biotechnology Council, 2008, 2009, 2010, 2011).

The Massachusetts Life Sciences Collaborative

The Massachusetts Life Sciences Collaborative was formed in 2006 and founded by a leadership council originally composed of representatives from Harvard, MIT, University of Massachusetts, and Genzyme. The Collaborative's mission is to support growth in the life sciences, and its current priorities address the value chain, business environment, and human capital needs of the industry cluster. This includes a focus on manufacturing and clinical trials, as well as workforce development and community college training programs. Financial support for the Collaborative comes from The Boston Foundation, Harvard, MIT, UMass, the Massachusetts Technology Collaborative, and the Massachusetts Life Sciences Center. An initiative of the Collaborative, the BioManufacturing Roundtable, brings together industry, academia, and state officials to work on a growth strategy in life sciences manufacturing for the state (Massachusetts Life Sciences Collaborative, 2006, 2008).

Community colleges and workforce development

Community college programs have received attention as a viable mechanism for building the mid-skilled and entry-level workforce in the Massachusetts biotechnology sector. Biotechnology programs offered through community colleges provide both two-year associate degrees and one-year certificates. These programs prepare students for technician jobs in manufacturing and laboratory environments. Many of these programs have grown over recent years, and a few, like Middlesex Community College's biotechnology technician program, have become well known

There are 15 community colleges in Massachusetts. Eleven of them have biotechnology-related programs in place and are engaged in the Massachusetts Life Science Education Consortium (MLSEC) and/or have become known for their program through other means. Table 2 provides a list of these institutions and the corresponding program names. Also included in the table is a list of the employers (if available) that have engaged with a specific program. The table provides additional information on whether the program received an endorsement from the MLSEC, whether the program has had students participate in the MLSC Internship Challenge, and whether the program/institution has received equipment and supplies grants from the MLSC.

Table 2: Biotechnology related programs offered through Massachusetts community colleges

Institution Name	Biotechnology-related Program Title(s)	Engaged Employers	MBEF – Com-munity College Endorse-ment Rating	Student Partic-ipated in MLSC Intern-ship Chal-lenge	Received MLSC Equip-ment/ Sup-plies grant
Berkshire Community College	Associate in Arts - Biotechnology Concentration	Nuclea Biotechnologies	Silver	No	Yes (w/ Nuclea)
Bristol Community College	Associate in Arts in Liberal Arts & Sciences - Biotechnology/Bio medical Technology and BioManufacturing	unknown	n/a	No	Yes
Bunker Hill Community College	Biological Science Program	unknown	Silver	2010	n/a
MassBay Community College	Biotechnology/ Marine Biotechnology/ Forensic DNA Science Program	SBH Sciences; Genzyme; Organogenesis; Mattech	n/a	2009/10/ 11	Yes
Middlesex Community College	Biotechnology Technician, A.S. and Certificate	Genzyme; Wyeth; Millipore; EMD; Biogen Idec	Gold	2010/11	Yes
Mount Wachusett Community College	Biotechnology/ Biomanufacturing	BMS	Silver	2010/11	Yes (w/BMS)
Northern Essex Community College	Associate in Applied Science in Laboratory Science	unknown	Gold	No	n/a
North Shore Community College	Biotechnology (1 and 2 year)	Wyeth; Genzyme	n/a	No	n/a

Quinsiga-mond Community College	Biotechnology Certificate (1 year)	Genzyme; AstraZeneca; Athena Diagnostics; Charles River Labs	Gold	2009/11	n/a
Roxbury Community College	Biotechnology Associate of Arts Degree Program	Merck	Gold	2010	n/a
Springfield Technical Community College	Biotechnology/ Biomanufacturing A.S.	Microtest; New England Peptide	Silver	2010/11	n/a

Associate degree and certificate programs provide hands-on laboratory training in biotechnology, cell culture, protein purification, and recombinant DNA technology. Programs provide training in aseptic technique, media preparation, quality control/GMP, documentation, and validation. Many programs also highlight organizational and work skill training regarding communication, teamwork, and time management. Programs are designed to prepare students for entry-level jobs as research assistants, lab technicians, manufacturing technicians, and for positions in quality control, documentation, and instrumentation calibration. Program credit can be transferred to four-year programs (Holgate, 2009; Kriz, 2011).

Other workforce development activity

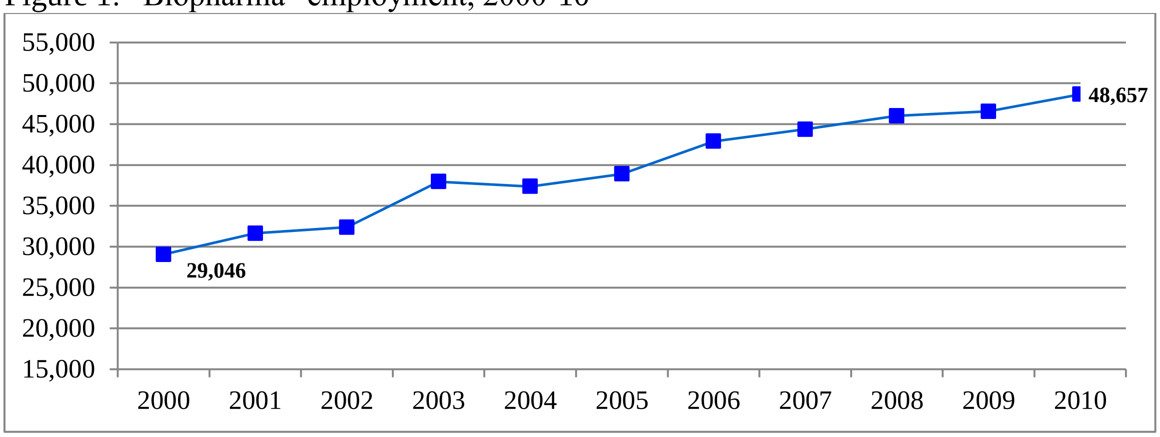
The state's workforce development (WFD) system is charged with assisting the state's administration in achieving economic development goals like those of the Massachusetts Life Sciences Center. Workforce development stakeholders support the sector's need for high-skilled professionals, but also have an immediate interest in expanding job opportunities for low-skilled and mid-skilled job seekers as well as serving particular demographic groups (e.g. displaced workers, veterans, and young adults). Workforce development programs try to target good jobs that offer career paths and training opportunities that allow individuals to increase their skills and earn a decent living. Entry-level technician jobs in the life sciences are one such example. Further, workforce development programs can be designed to specifically offer services to unemployed workers, especially during tough economic times. Workforce development programs also help ensure services for veterans and assist young adult's transition from school to career (Executive Office of Labor and Workforce Development, 2008).

Recently, Massachusetts WFD stakeholders have been focused on mid-skilled jobs and the shortage of appropriately trained workers. This mirrors the national focus. Workforce development stakeholders have launched a "skills2compete" campaign to help promote training and educational opportunities for mid-skilled workers, stating that everyone should be guaranteed at least two years of post-secondary education. According to recent research, about 45 percent of jobs in Massachusetts can be classified as mid-skilled, but only 32 percent of workers have the credentials to fill them. Building the mid-skilled workforce will help ensure long-term competitiveness for the state as well as help workers advance in the labor market (Skills2Compete et al., 2010).

Industry and economic development timeline for the Massachusetts life sciences industries

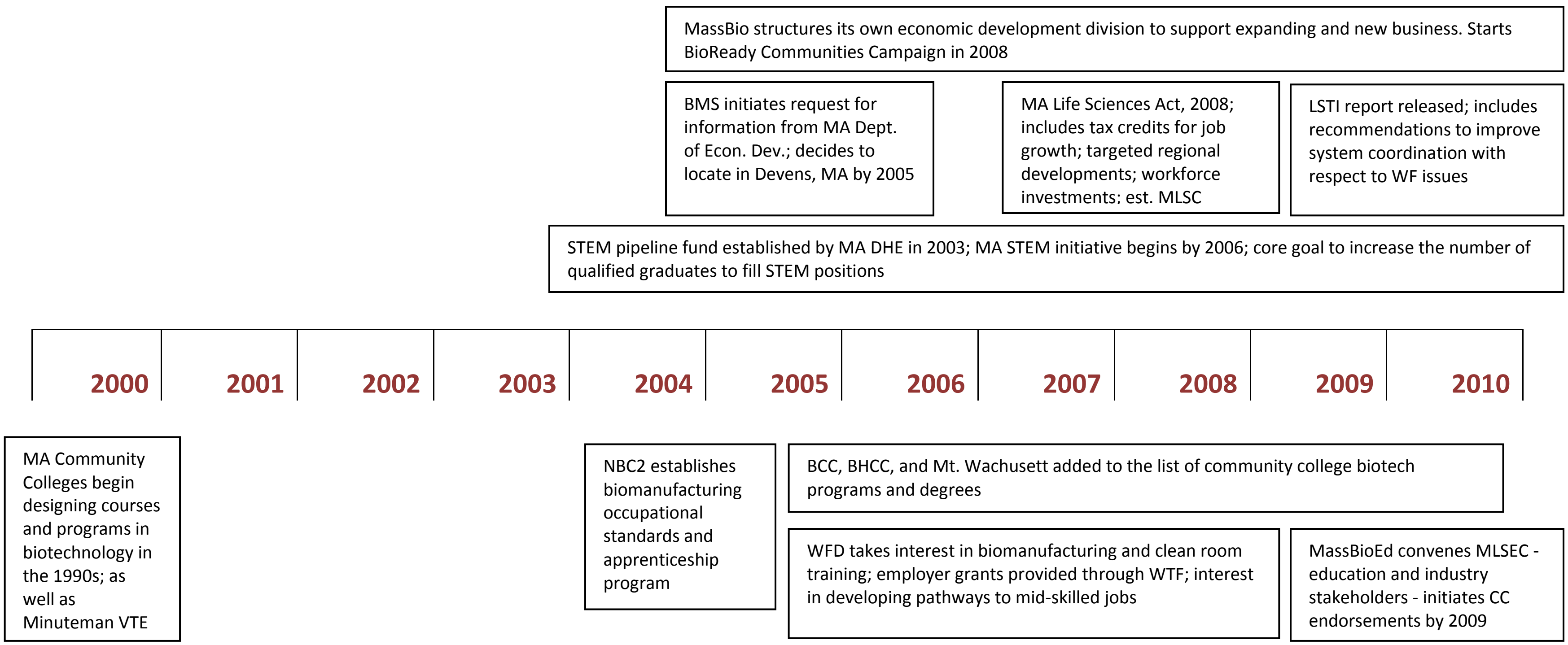
The case study uses time series analytics (as described by Yin, 2003b) to investigate changes that have occurred due to the increased economic development activity in Massachusetts, especially during the last half of the decade. The timeline (Figure 1 and Figure 2) shows a number of policy tools and initiatives put in place that both invest in biotechnology jobs and attempt to address the distribution of jobs across different skill groups and sub-state regions. The timeline also shows that this uptake in policy strategies follows Bristol Meyers Squibb's decision to locate its largest biologics manufacturing facility in the state of Massachusetts. Following Figure 1 and Figure 2 is a chronological description of economic development in the life sciences as well as some historical context prior to the 2000s in Massachusetts.

Figure 1: "Biopharma" employment, 2000-10



Source: MassBio (2010, 2011)

Figure 2: Timeline for economic development policies and initiatives in the 2000s



1980s and 1990s

Massachusetts is home to two of the longest established dedicated biotechnology firms in the nation, Biogen (founded 1978) and Genzyme (founded 1981 and now owned by Sanofi); as well as Boston Scientific (founded in 1978) which is often credited as an industry founder within the medical device technology cluster for the state. Massachusetts also has the oldest biotechnology state trade association in the nation (founded in 1985). As well, in 1996, MassMEDIC was formed as the state's trade association for medical device and equipment manufacturers.

During the 1980s, the state's research universities played a dominant role in expanding technology in the life sciences. The 1990s then saw significant increases in venture capital investments for startup companies in the industry, which emphasized the entrepreneurial nature of moving science to industry (Powell et al., 2010). Thus, the 1990s was a period of high growth for life sciences industries in Massachusetts, and by the end of the decade, the Massachusetts biotechnology cluster included 58 publicly traded companies and 33 firms with more than 100 employees (Brookings Institution, 2002). Additionally, the medical equipment and device (MED) manufacturing sector grew during the 1990s. However, employment peaked in June of 1998 – as did other manufacturing in the state (Clayton-Matthews, 2001).

In addition to the tremendous contributions of the state's universities with respect to research, collaboration, and the production of a highly skilled workforce through baccalaureate and graduate programs, other education and training efforts began to develop through the community college system. Middlesex Community College established the state’s first biotechnology program at a community college. This includes a certificate program and an associate’s degree program. Since 1990, the program has had about a 50 percent graduation rate. This compares favorably to average graduation rates for community colleges (about 20 percent). The program has engaged at least ten biotechnology employers that provide internships and most often hire graduates. Wyeth (now part of Pfizer) has been an important partner to the program, hiring about 40 graduates within a ten-year period (UMass Donahue Institute, 2008). By 1996, Mass Bay, North Shore, Quinsigamond, and Springfield Technical community colleges had launched biotechnology related certificate and degree programs. Also, in 1995, Minuteman Vocational Technical High School established a biotechnology area of study for its regular high school students and another for participants in its adult education and training program (Breznitz, 2006).

Early 2000s

During the 2000s, the core life sciences industries, particularly those associated with biotechnology, have been high performers relative to the rest of the innovation economy. MassBio reported that employment in biotechnology grew consistently through the 2000s, suggesting that the industry was recession proof (Massachusetts Biotechnology Council, 2011). Many other high tech industries have not recovered to pre-2001 levels and have negatively impacted Massachusetts performance during the 2000s (see for example, Bradbury & Kodrzycki, 2007). MED employment declined during the recession although total payroll increased. MED had some productivity gains likely due to changes in the industry mix; higher paying jobs grew in electromedical apparatus manufacturing while relatively lower paying jobs in laboratory apparatus and furniture declined (Clayton-Matthews & Loveland, 2004).

Biotechnology and other life sciences industries have been regionally concentrated within the state. Industry is clustered in Cambridge, Boston, Woburn, Waltham, Lexington, and Worcester (Breznitz, 2006). For example, in 2002, Cambridge had 30 percent of firms and 60 percent of employment in biotechnology (Breznitz & Anderson, 2005). A number of regional initiatives were formed to support innovation industries, particularly biotechnology. The Massachusetts Biomedical Initiative (established in 1985 in Worcester) provides business incubator space and other support for startup companies. In addition, the Pioneer Valley Life Sciences Institute formed in Springfield in 2002, LifeTech Boston, which was launched by the City of Boston in 2003, and the John Adams Innovation Institute founded in 2003 and supported by the Massachusetts Technology Collaborative.

With respect to education and training, MassBio formed the Massachusetts Biotechnology Education Foundation (MBEF) in 2001. This independent nonprofit organization was charged with assisting MassBio members with their training and education needs. It has developed into a unique intermediary that links education, industry, and government in support of furthering the state’s competitive advantage in biotechnology and the life sciences (Massachusetts Biotechnology Education Foundation, 2009).

Late 2000s

According to MassBio (Massachusetts Biotechnology Council, 2011), "biopharma"[3] employment increased 23 percent from 2001 to 2005 and increased an additional 24 percent from 2005 to 2010 (see also Figure 1). This sustained employment growth in the sector has been driven by research and development services in biotechnology. Massachusetts has the highest concentration of bioscience research and development in the country. The location quotient (LQ) is a common measure of industry concentration; it is the ratio of industry employment to total employment for one region relative to the entire nation. The LQ provides an estimate of the extent to which an industry concentrates in a particular region. An LQ greater than 1 implies that an industry is concentrated in a region when compared with the nation as a whole. In 2010, the LQ for R&D in biotechnology was 7.42 in Massachusetts relative to the United States (the next highest state was Maryland with 3.74). Another indication of growth in "upstream" activities is that biotechnology companies in Massachusetts have captured a growing share of venture capital. In 2000, Massachusetts biotechnology companies received 12 percent of venture capital financing for the sector; whereas in 2010 they had received 23 percent (equivalent to $850 million in 2010). However, of concern to the industry, funding from the National Institute of Health (NIH) has been flat. In 2010, Massachusetts received about $2.4 billion in NIH funding. This amount has been level since 2003, with the exception of additional funding through the American Recovery and Reinvestment Act in 2009.

[3] MassBio defines "biopharma" as research and development in biotechnology and pharmaceutical manufacturing.

Since 2006, Massachusetts has added over 1,500 jobs in biopharma manufacturing – more than any other state in the sector. However, biopharma manufacturing employment for almost all states (including Massachusetts) was flat between 2009 and 2010. Also, research from the Center for Labor Market Studies at Northeastern University has shown that the location quotient for pharmaceutical manufacturing is close to one in Massachusetts, which does not indicate a strong concentration in the state (Khatiwada & Sum, 2006). Meanwhile, throughout the 2000s, MED manufacturing employment contracted from about 15,000 in 2001 to 10,750 in 2010 resulting in a declining concentration of industry employment for the state (U.S. Department of Labor - Bureau of Labor Statistics, 2012b).

In 2005, Bristol Meyers Squibb (BMS) indicated interest in locating in Massachusetts and submitted a request for information. Given the increase in biologics production in the past decade and the manner in which biotechnology and pharmaceutical companies are making new locational decisions at a global level, economic development actors in Massachusetts came to realize that the state needed to compete in attracting manufacturing activity. Other states such as California and North Carolina were engaged in similar efforts. The BMS case launched additional and ongoing economic development activity (Abair, 2011). The state's significant efforts to meet the information and planning needs of BMS were rewarded and in 2006, BMS decided to establish new operations in Devens, Massachusetts.

Responding to the BMS information request prompted MassBio to create its own economic development department, which is intended to serve the state. MassBio's economic development program works in collaboration with a number of state agencies and trade groups to help businesses with location decisions and to navigate the permitting process (Abair, 2011; Massachusetts Technology Collaborative, 2006). In 2008, the economic development program launched its BioReady Communities campaign, which provides ratings for municipalities across the state based on locational advantages for biotechnology companies (Massachusetts Biotechnology Council, 2008).

A number of efforts were launched specifically for manufacturing from 2004 to 2008. The Northeast Biomanufacturing Consortium (2004) helps coordinate education and training initiatives for the sector both locally and nationally. This included establishing an apprenticeship program for entry-level biomanufacturing jobs through grant funding from the National Science Foundation. In 2006, the Massachusetts Life Sciences Collaborative was formed. By 2008, the Collaborative helped establish the Biomanufacturing Roundtable – a sector specific working group to help establish growth strategies for the region (Massachusetts Life Sciences Collaborative, 2012; Northeast Biomanufacturing Center and Consortium, 2012).

During this same period, state workforce and education policies or initiatives were taking root. One broad reaching initiative in Massachusetts is the Science, Technology, Engineering, and Mathematics (STEM) initiative, overseen by the Massachusetts Department of Higher Education. Since 2003, this large collaborative effort has worked to promote STEM careers, provide professional development for teachers and faculty, and help strengthen the pipeline of high-skilled workers in science, technology, engineering, and mathematics fields. This is also the time period when workforce development stakeholders entered the playing field. One of the first WFD initiatives launched in the state to help develop needed mid-skilled jobs in biotechnology was called BIOTRAIN. This was a collaborative effort funded through the Commonwealth Corporation and included MBEF, and Bunker Hill and Middlesex community colleges.

Community colleges programs are viewed as a viable mechanism for building the mid-skilled and entry-level workforce in the Massachusetts biotechnology sector. This focus has led to additional biotechnology programs offered through Bunker Hill, Bristol, and Mt. Wachusett community colleges. Mt. Wachusett (MWCC) is one of the newer programs; begun in 2007, the program offers a two-year associate's degree and a one-year certificate. MWCC received a $1.6 million three-year grant from the Department of Labor to build its credit programs and to develop a non-credit pre-employment workforce-training program. This capacity building grant effectively started in September 2008 with a 15-week course. Non-credit training of this sort helps employers meet their immediate short-term needs (Holgate, 2009).

In 2008, the Life Sciences Act was passed in Massachusetts. It established a $1 billion, ten-year initiative to encourage innovation, accelerate products for commercialization, fill funding gaps, and expand the workforce available to relevant industries, including biotechnology (Executive Office of Housing and Economic Development et al., 2007). The Massachusetts Life Sciences Center (MLSC) was created under the Act as a quasi-public organization charged with implementing this large economic development initiative. MLSC is affiliated with, but not controlled by, the Executive Office of Housing and Economic Development (Massachusetts Life Sciences

Center, 2010; Windham-Bannister & Mudawar, 2010). The Act included a number of targeted investments using capital funds, research grants, and matching funds to spur job growth, support innovative research, and strengthen the training and education system. This included $15 million to invest in workforce development. The Act also created a tax credit program to encourage job growth which mandates that qualified companies create new jobs for full-time permanent employees ("An act providing for the investment in and expansion of the life sciences industry in the commonwealth," 2007; Patrick, 2007).

Following the completion of the Life Sciences Talent Initiative in 2008, MBEF and other stakeholders strategized on ways to better connect industry with the state's college and university programs. The LSTI report had indicated that there was a disconnect between the higher education system and industry. Evidence collected from focus groups and surveys suggested that employers did not understand what new efforts the system of higher education had implemented. Further, a survey of education and training programs showed that biotechnology and other industry relevant programs were many and varied. To address the apparent lack of information, The Massachusetts Life Sciences Education Consortium (MLSEC) was formed in 2009 under MBEF's leadership to help create linkages between the higher education system and industry employers (Hartford, 2010).

Most recently, Massachusetts workforce development stakeholders have been focused on the shortage of appropriately trained workers for mid-skilled jobs. This focus on the mid-skilled workforce is mirrored at the national level. Workforce development stakeholders have launched a skills2compete campaign to help promote training and educational opportunities for mid-skilled jobs, stating that everyone should be guaranteed at least two years of post secondary education (Sasser Modestino, 2010; Skills2Compete et al., 2010). In 2011, the state community college system was awarded a three-year, $20 million grant to improve coordination across education and training programs as well as with the workforce development system. These grant activities will focus on key industries for Massachusetts; this includes biotechnology and the life sciences. These efforts are targeting dislocated and unemployed workers. The goals of the grant are to increase the number of students able to complete these programs, experiment with accelerated curriculums, increase industry and Workforce Investment Board (WIB) involvement, and enhance student supports (Allen, 2011; Commonwealth Corporation, 2011).

This case study was conducted in a particular context – that of Massachusetts in the years 2000 to 2010 with particular stakeholders that have helped shape the economic development agenda. Public and private collaboration and investment has successfully spurred the industry. The question now is whether or not this increased economic development activity has not only supported industry and regional competitiveness, but has it identified and supported equity goals such as improving access to mid-skilled jobs, increasing workforce diversity, and helping different regions across the state grow.

CHAPTER 4

METHODOLOGY

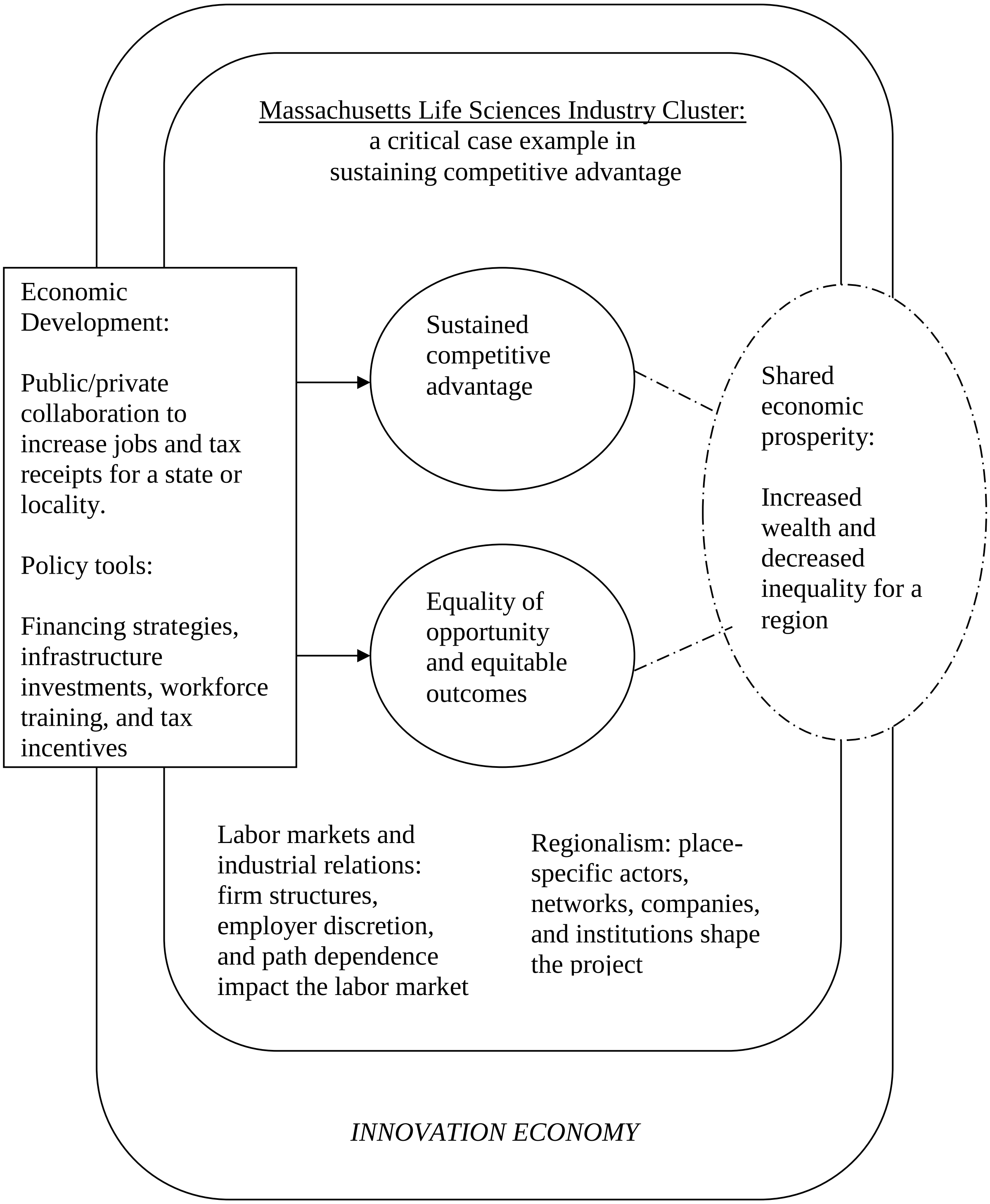
This research uses standard case study methodology (Yin, 2003a, 2003b) to assess labor market and regional changes resulting from economic development policies. It examines the extent to which equity as opposed to efficiency is considered a goal of the policies and it takes a step toward defining the role of equity goals in supporting the innovation economy. Efficiency is defined here as sustained competitive advantage or continuous innovation to improve productivity and product and service quality. The research uses three measures of equity: broadly, equity refers to reduced disparity in worker income; in the specifics of the case, equity refers to an equitable distribution of economic benefits; equity is evidenced as equality of opportunity when individuals have access to jobs regardless of gender, race or other characteristics. The case study relies on several analytical strategies to demonstrate links between economic development initiatives and policies with labor market outcomes including time series analytics and comparisons of life sciences with other industries in the Massachusetts innovation economy. Case study findings and a case level analysis are reported along with a discussion of relevant policy issues. Case evidence is drawn from three sources: documentation, secondary data sets, and interviews with stakeholders.

Conceptual Framework

The conceptual framework that guides this inquiry is depicted in

Figure 3. The largest rectangle marks the innovation economy, which is the context that surrounds the case study. The inner rectangle represents the critical case study of the Massachusetts Life Sciences industry cluster. Economic development is a broad field that works through public/private collaboration to increase jobs and tax receipts for a region. The creation of economic development agendas and project implementation occurs across the Massachusetts industry base. With respect to the life sciences, primary economic development tools have included financing strategies, infrastructure investments, workforce training, and tax incentives. The case study research connects economic development strategies to outcomes related to sustained competitive advantage and equity goals. Ultimately, the case study seeks to understand how shared prosperity might be achieved in Massachusetts given the life sciences industries; the extent to which increased wealth in the life sciences is accompanied by equality of opportunity and equitable (or fair) outcomes across the state. Finally, the case study examines a series of intervening factors drawn from the literatures on labor markets and industrial relations and regionalism.

Figure 3: Conceptual framework for a case study of the Massachusetts life sciences industries



Industry description and outlook for biotechnology and other life sciences

In the United States, researchers using public data sets through the U.S. Census Bureau and the U.S. Bureau of Labor Statistics define regional biotechnology and life sciences clusters in one of two ways. One strategy defines firms and workers classified under the 2007 North American Industry Classification System (NAICS) 6-Digit code 541711 or “Research and Development in Biotechnology.” This definition underestimates total biotechnology activity because it does not include firms and workers that use it, only those that develop it. Alternatively, some researchers (as is the case with Massachusetts) identify biotechnology as part of a larger cluster, that is, “Life Sciences.” This measurement strategy includes biotechnology R&D with associated industries in healthcare, pharmaceutical, and medical device manufacturing. This method overestimates the extent of biotechnology activity because it includes very large firms, which may only have a small proportion (if any) of their operations dedicated to biotechnology-related activity. At the same time, this treatment ignores biotechnology activity in industries outside of human health. Further, most researchers supplement their data with proprietary sources (Sum et al., 2007b; van Beuzekom & Arundel, 2009).

The Massachusetts Departments of Economic Development and Labor and Workforce Development (2007) have identified the biotechnology and life sciences industries most relevant to the state. Industries are defined using the NAICS codes. The core life sciences industries include pharmaceutical, medical equipment and device, and instruments manufacturing as well as research and development services. Life sciences supporting industries include some additional manufacturing, wholesale, technical services, health insurance, and healthcare providers. In addition, NAICS codes have been used to identify other high tech industries. Some high tech industries overlap with the life sciences, but also include computer and communications equipment and electronic components manufacturing. High tech service industries include architectural and engineering, data processing, and computer design. Core life sciences and high tech industries constitute the base of the innovation economy in Massachusetts. This case study analysis relies on NAICS codes to identify biotechnology and other life sciences and focuses on the core life sciences industries. When relevant comparisons can be made, data is used to describe the supporting life sciences industries and other high tech industries. (See APPENDIX B for a detailed list of NAICS codes and descriptions.)

Based on the wealth of research available on industry performance in the core life sciences for Massachusetts, we know these industries are contributing to the state's economy by providing a growing number of good jobs (i.e., high wages with benefits) and that research and development services have been the primary driver of that growth. Medical equipment and device manufacturing has restructured and declined some in the past decade, while pharmaceutical manufacturing has grown. However, it remains unclear whether pharmaceutical manufacturing employment growth will continue or achieve a high concentration relative to other states. During this past decade of growth, labor market research has emphasized the high skilled nature of many of the jobs in the life sciences cluster and a shortage of medical, business, and technical personnel (Clayton-Matthews & Loveland, 2004; Khatiwada & Sum, 2006; Massachusetts Biotechnology Council, 2011; Sum et al., 2007a; UMass Donahue Institute, 2008).

Definitions of biotechnology and its application in the life sciences

Biotechnology is a set of processes and products that combine biology and life sciences with technology. The Organisation for Economic Co-operation and Development provides a standard definition of biotechnology: “the application of science and technology to living organisms, as well as parts, products and models thereof, to alter living or non-living materials for the production of knowledge, goods and services” (BioTalent Canada, 2008b; Industry Canada, 2000a, 2000b; van Beuzekom & Arundel, 2009). The OECD also provides a list-based definition that includes firms that use and develop core technologies such as DNA/RNA applications, protein and peptides/enzymes, cell and tissue culture, and engineering, gene, and RNA vectors, bioinformatics, nanobiotechnology, process biotechnologies, and sub-cellular processes (van Beuzekom & Arundel, 2009). Biotechnology is also generally defined by its application within an industry sector, for example in human health, agriculture, and bioinformatics. Three quarters of all biotechnology activity worldwide occurs in the field of human health (BioTalent Canada, 2008b; Industry Canada, 2000a, 2000b; van Beuzekom & Arundel, 2009).

Recent research has defined and measured economic activity within the life sciences in various ways. Common measurements used to define and track performance are counts of employment, job vacancies, payrolls, earnings and tax receipts; number of firms, types of firms and firm size; commercial sales, R&D expenditures, venture capital and government research funding; number of patents, number of products (,e.g., available drugs), and number of clinical trials underway; location quotients, multiplier effects and social network analysis; alliances between firms through technology transfers, joint research and merger and acquisition activity (BioTalent Canada, 2008a, 2008b; Christopherson & Clark, 2007; R. W. DeVol; Perry; Ki, Junghoon; Bedroussian, Armen; Koepp, Rob, 2004; Industry Canada, 2000a; Sum et al., 2007b).

<u>Economic and occupational outlook for biotechnology and other life sciences</u>

The vast majority of biotechnology activity (both research and development and commercial) is in human health. The production of biotechnologies occurs over a long time horizon. In addition to developing a skilled workforce, industry players face challenges securing financial backing and addressing regulatory issues over the duration of a project. Other hurdles include consumer acceptance; lack of market information; access to technology; and, international harmonization. The United States has experienced impressive growth rates in biotechnology-related employment and has built up its export base in biopharmaceuticals (Industry Canada, 2000b; Sum et al., 2007b).

The industry is organized around research and development, clinical trials, and production and commercialization activities. Research and development includes lab testing, discovery, applying for patents, and the pre-clinical trial phase. Once flagged as viable, a discovery enters into clinical trials. Venture capital or other financial resources are required to fund the trials until the product or process is approved for market. Once a biotechnology project has been approved and funded for production, then business and management expertise is required for commercialization. Overall, a strong industrial base within a region will contain at least one academic anchor in basic research; a mix of firms (start-up, high-growth, and publicly traded), as well as a range of business services; and an institutional base that provides the infrastructure and processes needed to innovate, finance, and commercialize projects (Industry Canada, 2000b; Nasrullah, 2009; North Carolina Biotechnology Center, 2003).

Some states, like North Carolina, have been able to attract new manufacturing jobs related to biotechnology. The new manufacturing facilities operate near an established cluster where process innovation is still occurring. Research shows that once a product has been commoditized, firms are likely to consider off shoring operations to cut down on tax obligations and labor costs (North Carolina Biotechnology Center, 2003; Reynolds, 2009).

The pharmaceutical industry has undergone serious restructuring since the 1980s. The rise of biotechnology itself has contributed to these changes. Additionally, cost and pricing pressures, regulatory controls, and global markets have contributed to changes in the industry. Large vertically integrated firms are declining, discovery has lagged and there will be a disproportionate number of patents expiring on blockbuster drugs. But despite these pressures, profitability remains high, steady, and non-volatile in the pharmaceutical industry (Kapler & Puhala, 2008).

The majority of jobs within the life sciences are in management, scientific, professional, and technical occupations. Speaking broadly about the scientific research and development services industry[4] in the U.S., 68 percent of workers hold a bachelor's

[4] This includes the aerospace, automotive, biotechnology, chemical and materials science, electronics, nanotechnology, and pharmaceutical fields.

degree or higher. Additionally, 47 percent of workers in R&D are working in science, technology, engineering, and mathematics (STEM) occupations; 20 percent are in management positions; and 15 percent perform administrative support. Jobs in biotechnology-related firms tend to pay more than the regional average. For example, average annual earnings in Massachusetts bio-pharmaceutical industries were $56,000 in 2005 as compared to $32,000 for all workers in Massachusetts during that year. These jobs are also more likely to be full-time than those in other industries and they attract a large percentage of foreign-born workers (Sum et al., 2007b; Terrell, 2005). When a regional biotechnology sector begins to develop downstream operations, mid-skilled jobs increase and new job opportunities open up for the local workforce. A needs assessment of the North Carolina biomanufacturing workforce showed that 67 percent of workers needed an associate's degree or less, 27 percent needed a bachelor's degree, and 6 percent needed a graduate degree (North Carolina Biotechnology Center, 2003).

Employers within biotechnology-related industries report a skills gap and limited qualified applicant pools in a number of occupations considered vital for growth and production. There are at least two explanations for the skills gap: One, high industry growth rates coupled with a high demand for specialized skills make a skill gap inevitable, especially at the top end of the labor market. This includes scientists as well as cross-disciplinary management and professional staff. Second, employers usually require industry-specific experience for new hires – including entry-level workers. Employers have reported the most difficulty hiring pre-clinical and clinical researchers, regulatory affairs staff, technicians and engineers, and marketing and sales personnel. These positions often require a four-year degree or less and they all require some industry knowledge and experience. These workforce needs are increasing for biotechnology firms, especially as "downstream" operations grow (e.g., clinical research and manufacturing) (BioTalent Canada, 2008a; R. W. DeVol, Perry; Ki, Junghoon; Bedroussian, Armen; Koepp, Rob, 2004; Munn-Venn & Mitchell, 2005; North Carolina Biotechnology Center, 2003; UMass Donahue Institute, 2008).

Components of the case study research design

The case study research design has five main components: the research questions; the unit of analysis or the object being studied; the use of pattern matching; and the criteria for interpreting findings. Each of these components is discussed below.

Research questions

1. Significant industry research has shown that Massachusetts is sustaining its competitive advantage in the life sciences, particularly with respect to research and development. There is also growing interest among economic development stakeholders in supporting manufacturing and clinical trial operations as a way to expand the economic benefits of the industry. How can sustained competitive advantage in the Massachusetts life sciences industry be measured and have downstream operations (e.g., manufacturing and clinical trials) expanded in Massachusetts?

a. Has Massachusetts sustained competitive advantage in the life sciences since 2000 and, if so, how does it compare to other high tech sectors in the innovation economy?

b. To what extent has sustained competitive advantage been achieved in the "downstream" activities of the life sciences (e.g., in manufacturing and clinical trials)?

2. Massachusetts has a strong and growing industry cluster in the state with many important assets, particularly its university and health systems and its access to venture capital. This growth has contributed to the stock of good jobs. Jobs in the life sciences are highly paid even at entry level and are well benefited. Has the growth in good jobs in the core life sciences industry been accompanied by more equitable outcomes and, in particular, have the number of life sciences jobs grown in regions outside of the metropolitan core and has workforce diversity expanded along with industry growth?

    a. Has sustained competitive advantage in the Massachusetts life sciences been accompanied by an increase in earnings inequality?

    b. How have jobs grown across different regions in the state and how does this growth align with different economic development investments?

    c. How, if at all, has workforce diversity (e.g., in skill level, sex, race, ethnicity, veteran status, and nativity) expanded in the life sciences?

    d. How have "downstream" activities contributed to the industry mix across the state and the occupational structure within the industry?

e. To what extent has the Massachusetts core life sciences industry contributed to more equitable outcomes with respect to sub-state regional growth and workforce diversity when compared to the rest of the innovation economy?

3. Given what is learned about sustained competitive advantage and equitable outcomes, do stakeholders view the balance between the two as a tradeoff or an opportunity for shared prosperity? The third research question seeks to shed light on how equity goals and interests are incorporated into the economic development agenda. In concrete terms, how do stakeholders (e.g., development intermediaries, educators, and employers) view equity and efficiency as it relates to their role in supporting and growing the life sciences industry in Massachusetts?
    a. What are stakeholder views on industry outlook and regional competitiveness, particularly with respect to "downstream" operations?
    b. How do stakeholders view the objectives of economic development policies and initiatives with respect to efficiency and equity?
    c. How have employers engaged in regional economic development initiatives and what have they gained?

<u>Unit of analysis</u>

The unit of analysis is the object of study in the case. The "case" represents economic and workforce development efforts in the Massachusetts life sciences cluster.

The case study pays particular attention to changes in the labor market and whether those changes are reflective of sustained competitive advantage and equitable outcomes. Analysis focuses on how jobs are held by region, skill, and worker characteristic; how the distribution of these jobs change over time; how those changes compare to the other sectors in the innovation economy; and how changes are linked to economic development efforts.

Pattern Matching

Time series analytics allow for pattern matching. The timeline for the case study is 2000 through 2010. The case study uses 2005 as an approximate year that marks the start of a significant ramping up of policy and initiatives related to the life sciences industries in Massachusetts. This build up follows on the decision of a multinational pharmaceutical corporation to locate its largest biologics production facility in Massachusetts. Comparisons between the two time periods will show differences (if any) in outcomes during the 2000-05 period versus the 2005-10 period. For example, do outcomes that support competitive advantage (e.g., employment growth) intensify during the latter period of the decade and coincide with increased economic development activity?

Lastly, pattern matching can be applied to a comparison with other industry clusters in the innovation economy. These comparisons are opportunities to provide additional support for (or against) linkages between industry and labor market outcomes and economic development policy. For example, how does workforce diversity compare between the life sciences industries and other high tech industries?

Criteria for interpreting findings

Data triangulation is a method that allows for comparing evidence provided by multiple sources. When findings are corroborated by three different sources, this condition permits for stronger casual inferences by the researcher. This method is used in the case analysis.

Limitations

The case study is limited in creating a causal claim between industry performance and labor market outcomes with economic development policies and initiative. We do not know whether industrial activity in the life sciences would have maintained and intensified in the absence of the new policies implemented in the second half of the 2000s. The combination of analytics used in the case study provides a best assessment of policy effects during the study period.

The timeline on the case study is limiting as well. Many of the policies and initiatives of interest very likely have effects that will extend well beyond 2010. The case analysis and policy discussion appreciate this artificial cut off in time – meaning that analysis assumes that there is more to come from these policies in the following years.

Rationale for choosing the case study method

In some respects, the research questions are straightforward. As the life sciences industries grow and mature in Massachusetts and as they continue to offer well paid promising employment opportunities, who gets access to the jobs and where are the jobs located? However, the research questions are also concerned with policy implementation and impact. What can be said about the impact of economic development policies and initiatives in influencing outcomes during the decade being studied? The influences of policy are occurring concurrently with other conditions. This includes the development path of industry and industry conditions. The trajectory of an industry within a particular region is influenced by the mix of companies, the actors (especially entrepreneurs, industry leaders, and investors), and by the socio-political environment. Industry conditions can change or intensify. Firm decision-making is done in the context of global competition; national policies impacting healthcare and research funding can influence company priorities; and the investment climate and business cycles help determine expansionary and cautionary times.

Further, the intention is not just to measure industry performance but to also gauge equality of opportunity and equitable outcomes. There is a wealth of research in biotechnology and life sciences alone that uses secondary and proprietary data to track, benchmark, and analyze industry performance especially related to investment, employment growth, educational attainment, patenting, and product development. Learning about the extent to which policies are geared toward equity requires a closer look at how policies and initiatives have been implemented and documenting stakeholder perspectives.

The case study method allows the researcher to investigate industry performance and equitable outcomes in a context that closely resembles the real complexities and regional specificity of economic development efforts. Broadly speaking, the case study methodology (in reference to economic development) acknowledges the specific context of a regional project. It can contribute to understanding the industry's trajectory, the development of governance structures, the role of institutions, and it can help identify promising practices in economic development and provide a forward-looking assessment of what might be next for the region.

Massachusetts has been selected as a critical case example to study because it is a leading state in the life sciences industries. Massachusetts ranks #1 in the Biopharm Innovation Index and #1 in the State Technology and Science Index. Research has shown that Massachusetts leads the nation in terms of human capital, STEM workforce, R&D inputs, and risk capital (R. DeVol et al., 2011; Milken Institute, 2004). In addition to leading the nation in the life sciences, Massachusetts is also experiencing high levels of income inequality and rapid increases in inequality relative to other states (see for example, McNichol et al., 2012).

Description of data sources

The case study relies on three main types of data and a range of methods for analyzing each source. These sources are documentation, secondary data sets, and interviews. They are each described below.

Documentation

A number of documents were reviewed for the case study analysis. This includes company and organization websites and annual reports, government documents, research specific to the life sciences cluster in Massachusetts, and media articles. The time frame for the documents was mostly between 2000 and 2010 in line with the case study timeline. Documents are used to describe particular policies and initiatives as well as supplement both the quantitative and qualitative analyses.

Secondary data sets

A number of public data sets are used in presenting case study evidence. These data are available through the U.S. Census Bureau and the U.S. Department of Labor, Bureau of Labor Statistics. This includes the Quarterly Census of Employment and Wages (2001-10), the Economic Census (1997, 2002, and 2007), the Census Population and Household Survey (5% PUMs 2000), and the American Community Survey Public Use Microdata Files (1-year estimates for 2005 and 2010). In addition to these sources, the clinical trials data available through the National Institutes of Health were analyzed.

When analysis required the comparison of dollar amounts over time, the Consumer Price Index – All Urban Consumers for the Northeast was used.

- Quarterly Census of Employment and Wages (QCEW): The QCEW data includes information on employment, establishments and payroll for workers covered by state and federal unemployment insurance programs. Data are available for 2001 going forward on a monthly, quarterly, and annual basis. Annual data extracted and tabulated from the QCEW for the case study included employment and payroll information for private sector establishments by 6-digit NAICS codes (see APPENDIX B) by state and metropolitan statistical area (MSA) using Microsoft Excel.
- Economic Census: The Economic Census provides detailed establishment statistics at national and local levels by 6-digit NAICS codes. The Economic Census began in 1935 and currently produces statistics every 5 years. Data for this case study were based on 1997, 2002, and 2007 and were downloaded into Microsoft Excel. Primary tables extracted for the case study are based on the Manufacturing – Geographic Series – Industry Statistics. These tables provide information on employment, establishment size, costs, shipments, and capital expenditures. In particular, information on shipments was analyzed. Shipments are defined as the net selling value of all products shipped plus other receipts for the year.
- Census 2000 and the American Community Survey (ACS): The 5 percent Public Use Microdata Sample files for the population and household survey for the

Census 2000 and the American Community Survey 1-year estimates for 2005 and 2010 were analyzed using Stata and/or SPSS. The U.S. Census website provides documentation for applying weights to the sample and for calculating margin of errors (U.S. Census Bureau - American Community Survey, 2009a, 2009b). The PUMS files for Census 2000 are available at the state level and represent a 5% sample of people and housing units for the area. The ACS files contain a subsample of housing units and the information on the people living in those units. ACS files are also available by state. The Census and ACS PUMS files provide detailed information on employment at time of survey, wage and salary earnings for the 12 months prior to the survey, and individual characteristics, including educational attainment. The three files also contain Census geographic codes. This includes PUMA codes which are assigned to the respondent's place of work. These codes are listed in APPENDIX B and categorized by sub-state region. These files are generally comparable across the three time periods. The U.S. Census Bureau provides guidance in interpreting comparability (e.g. changes in NAICS codes over time) as well as calculating standard errors and other statistics. The analyses in the case study followed Census guidance.

- ClinicalTrials.gov: The U.S. National Institutes of Health provides an online registry database for private and publicly funded clinical trials in the United States and around the world. Clinical trials are registered with the government as a precondition for publication. The online database is searchable by a number of variables, including start date, location, sponsor and disease and condition.

Clinical trials data was extracted and tabulated for studies starting between 2000-2010, which had at least one location in Massachusetts by sponsor type (e.g., public, industry).

Interviews

Interviews were conducted in 2010 and 2011 with targeted development intermediaries and employers. The three development intermediaries included the Massachusetts Life Sciences Center, Massachusetts Biotechnology Council, and MassBio's Education Foundation. The primary purpose of the interviews was to learn about the organization's mandates and particular policy initiatives relevant to the case study, as well as interviewee perspectives on labor market conditions for the state's life sciences industries. Interviewees were also asked to discuss how they saw their organization as supporting a well-functioning market or helping to solve a market or systems problem, especially with respect to entry-level and mid-skilled jobs. Interviewees were either heads of organization or program directors. The author interviewed one or two people from each organization and interviews lasted about one hour. These were very thoughtful and informative face-to-face interviews coming from organizations that hold a unique position within the state. Interviewees agreed to non-confidential interviews in the sharing of their expertise.

Employers were selected for recruitment for interviews based on several criteria. These criteria included being a commercial life sciences company registered as a member of MassBio and known to be engaged in at least one of the policy initiatives addressed in the case study. The author devised a recruitment list of twelve companies in Massachusetts that represented large companies, contract research organizations, and contract manufactures that were located across the state. Recruitment resulted in four confidential employer interviews that lasted 30 to 45 minutes. Semi-structured interviews were conducted face-to-face or over the phone with the human resource executive, operations executive or CEO. Gaining access to employers was challenging. Those that made themselves available were companies that were involved in a number of workforce education, training and coordination initiatives. The employer interviews are confidential.

Interview protocols are attached in APPENDIX C. Detailed notes were taken during the interviews and interview notes were cleaned and finalized immediately following the interview. Interviews have been reviewed multiple times and were coded by hand. The coding criteria are further detailed in the case study section on "Stakeholder Perspectives."

Other important qualitative sources that were used in the research to augment the interviews included attending a number of industry events and drawing on a summary report written by the author for the Massachusetts Workforce Board Association (MWBA). Industry events attended by this author include The Massachusetts STEM Plan in Sturbridge, MA, 2010; The State and Future of Biotechnology in Massachusetts at UMass Boston, 2009; Massachusetts Alliance for Economic Development Annual Conference, 2011; Life Science Engines in Cambridge, MA, 2007; Futures in Life Sciences program in Cambridge, MA, 2011; and Women Entrepreneurs in Science & Technology (WEST) in Cambridge, MA 2010. The summary report for MWBA titled

“Report on the Central Massachusetts regional biomanufacturing phone interviews” was based on findings from interviews conducted in 2009 by the author and includes perspectives from three additional employers and two educational providers.

CHAPTER 5

CASE STUDY FINDINGS

The case study findings are organized in the same manner as the research questions that are outlined in the METHODOLOGY chapter. Quantitative analysis is used to examine outcomes related to economic development priorities, including sustaining competitive advantage in the life sciences industries and particularly in downstream operations; the extent to which the innovation economy contributes to income inequality in Massachusetts; sub-state regional development and investments; changes and comparisons related to workforce diversity; and changes in the industry mix and occupational structure. As relevant, the quantitative analysis includes a review of recent industry research conducted in the Massachusetts life sciences or biopharmaceutical cluster. The final section draws on qualitative analysis of interviews conducted with stakeholders between 2009 and 2011 to provide a deeper understanding of industry outlook and economic development priorities, as well as employer perspectives. Overall, outcomes are derived using a variety of data sources to examine changes overtime. Particularly, the case study compares changes between two time periods – 2000 through 2005 and 2005 through 2010. The time period covered (2000-10) includes two business peaks and two periods of economic contraction. The periods of contraction begin in 2001 and the end of 2007. Unlike the life sciences, many industries had not recovered to pre-2001 employment and productivity levels before the 2007 recession started. The study also puts these changes into the context of the innovation economy and provides some comparisons with other high tech sectors.

Sustaining competitive advantage in Massachusetts

This section evaluates industry performance for the core life sciences from 2000 through 2010. The data analysis uses the Quarterly Census of Employment and Wages (QCEW) and focuses on changes in employment levels, location quotients and relative earnings. These are popular indicators used in other research to measure industry performance in biotechnology and other life sciences. Taken together over time, they show sustained competitive advantage in the innovation economy based on employment growth, the increasing concentration of industry, and maintaining high wages. Comparing these results to other high tech sectors[5] provides context for how the life sciences industries are doing relative to the rest of the innovation economy.

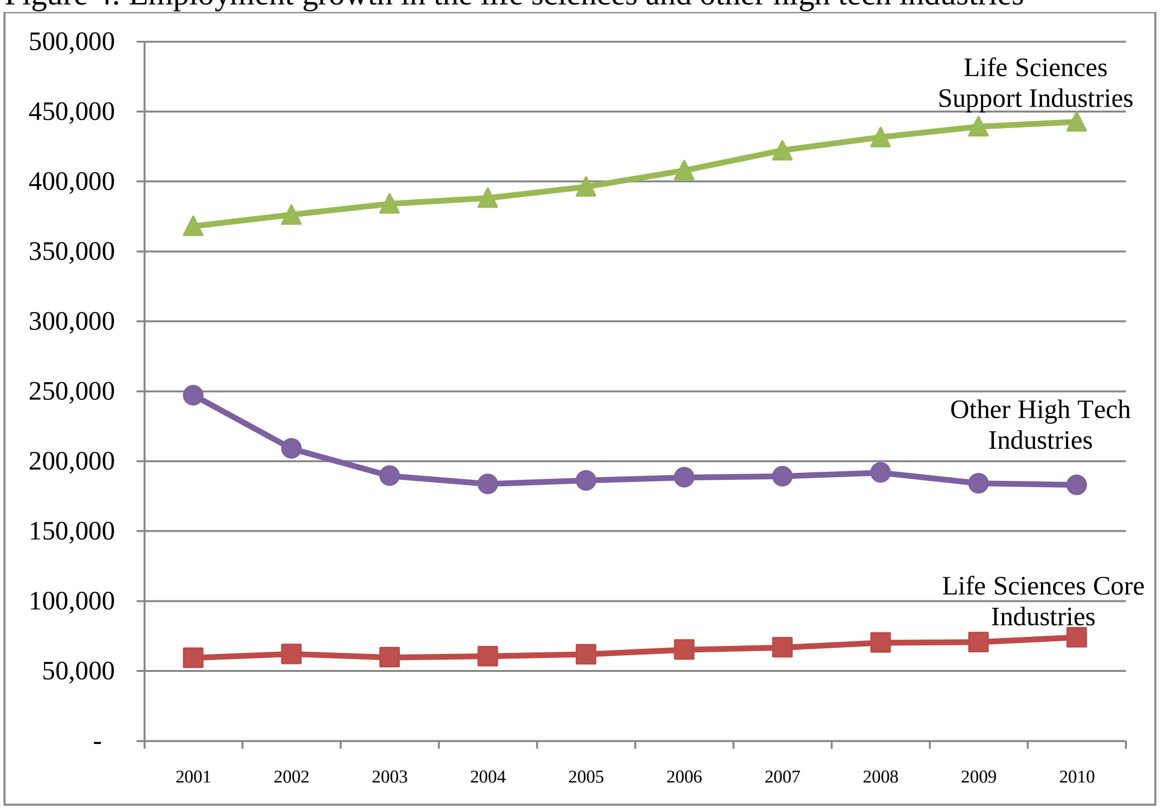
Employment growth

Employment growth provides an indication of whether the life sciences industries are expanding and how that expansion compares to other sectors in the economy, particularly other high tech sectors. According to data provided by the Quarterly Census of Employment and Wages (QCEW), employment in the core life sciences industries grew from about 59,000 in 2001 to 74,000 employees in 2010 (see Figure 4). Life

[5] The high tech sectors are defined in APPENDIX B and include industries like computer, communications, and electronics manufacturing as well as software development and other engineering.

sciences supporting industries have also continued to expand. In 2001, these industries employed 368,000 workers in Massachusetts and this workforce grew to almost 443,000 (by an average of 2.1 percent per year). With the exception of a slight dip in employment for the core life sciences in 2003, the core and supporting industries in life sciences did not contract in any other year between 2001 and 2010. This stands in contrast to other high tech industries that contracted in Massachusetts following the recession that started in 2001. High tech industries have not regained pre-recession employment levels from the beginning of the decade and they went through another contraction after 2007. On average, employment in high tech industries declined by 3 percent each year from 2001 to 2010.

Figure 4: Employment growth in the life sciences and other high tech industries



Source: Quarterly Census of Employment and Wages, 2001-10, author's calculations

Table 3 provides a detailed picture of growth rates in the three sectors. Life sciences employment experienced an average annual growth rate of 2.5 percent during a time that the private sector as a whole contracted 3.1 percent. Growth in life sciences employment was greater during the second half of the decade compared to earlier years. For example, growth in the core life sciences industries was much greater from 2005 to 2010 than in the earlier period (3.6 percent versus 1.1 percent).

Table 3: Decomposition of average annual growth for selected time periods by industry

Massachusetts -- Statewide	Life Sciences Core Industries	Life Sciences Support Industries	Other High Tech Industries
Average annual growth in employment (2001-10)	2.5%	2.1%	-3.1%
Average annual growth in employment (2001-05)	1.1%	1.9%	-6.6%
Average annual growth in employment (2005-10)	3.6%	2.2%	-0.3%

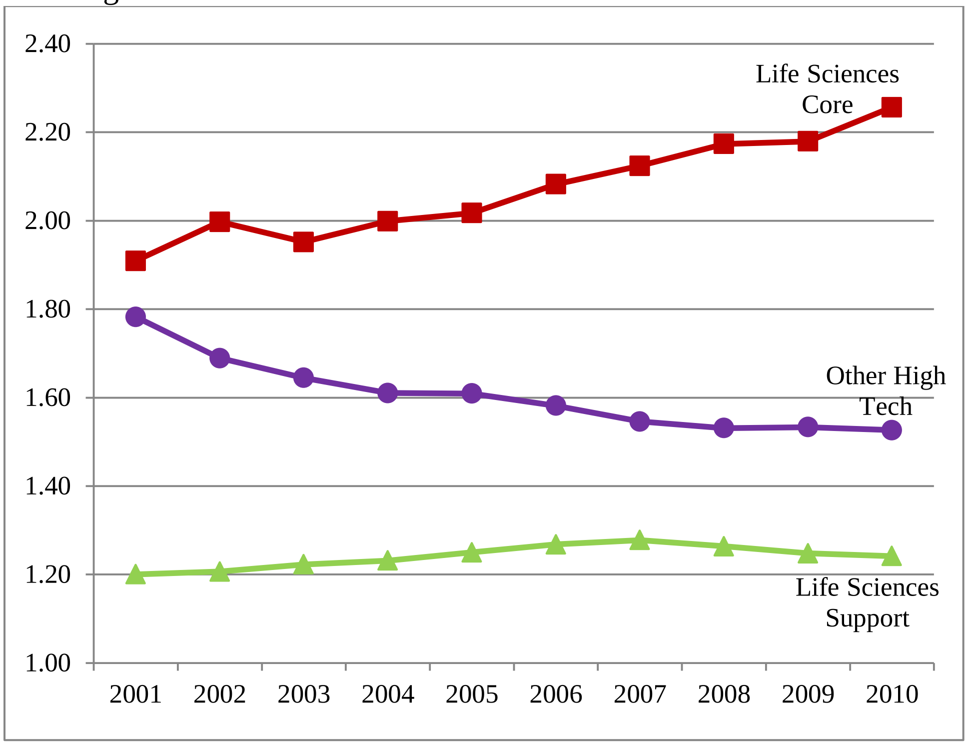
Source: Quarterly Census of Employment and Wages, 2001-10, author's calculations

Location quotient

Location quotients (LQs) are used to measure the regional concentration of an industry. LQs for the case study are calculated as the ratio of the proportion of life sciences employment relative to total private sector employment in Massachusetts to that of the U.S. Observing LQs over time is particularly interesting because it shows the extent to which Massachusetts life sciences employment is growing relative to the nation.

Location quotients for each of the three industry clusters are greater than one (see Figure 5). LQs greater than one indicates a greater concentration of industry employment in the state when compared to the nation. This means that these industries provide export base jobs that benefit the regional economy because they likely attract buyers from outside the region. For core life sciences industries the LQ has grown from 1.91 in 2001 to 2.26. Between 2005 and 2010, the LQ for core life sciences grew at rate more than twice what it had earlier in the decade. In contrast, high tech industries have seen the LQ go down over time from 1.78 in 2001 to 1.53 in 2010. This decrease in the LQ accompanied by the decrease in employment for high tech sectors suggests that competitive advantage is declining in this part of the innovation economy. Lastly, life sciences supporting industries have seen a stable LQ averaging about 1.2 during the decade.

Figure 5: Location quotient over time for core life sciences, supporting life sciences, and other high tech industries



Source: Quarterly Census of Employment and Wages, 2001-10, author's calculations

Relative earnings

Relative earnings are important because they compare earnings for workers in a particular industry with workers across the rest of the economy. Relative earnings in this section are defined as average annual wages for a sector divided by annual average wages for the private sector as a whole. First, Table 4 provides average annual earnings for each of the industry clusters and for the private sector as a whole. In 2010, average annual wages in the life sciences core industries was $106,262. Between 2004 and 2009 these wages grew on par with other high tech industries. Of interest, average annual wages in the life sciences supporting industries grew to surpass the economy-wide average during the 2000s. In 2001, the supporting industries average earnings were $7,000 below the annual average for the private sector, but by 2010 average life sciences supporting industries wages exceeded wages in the private sector ($58,401 versus $58,359 respectively).

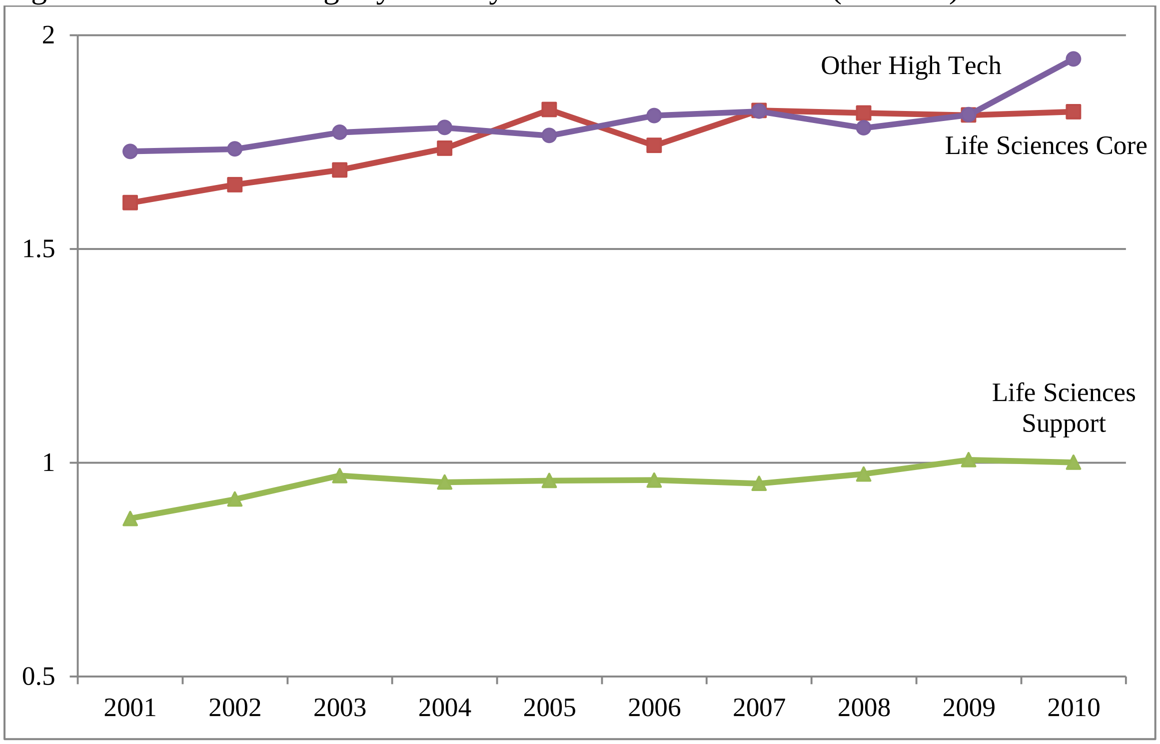
Table 4: Average annual earnings for Massachusetts by industry cluster (2010 $)

Year	Life Sciences Core Industries	Life Sciences Support Industries	Other High Tech Industries	Total Private
2001	90,822	49,120	97,622	56,492
2002	90,334	50,075	94,907	54,746
2003	91,351	52,577	96,127	54,231
2004	96,795	53,245	99,512	55,795
2005	101,002	53,010	97,642	55,330
2006	97,939	53,934	101,883	56,235
2007	106,244	55,420	106,148	58,261
2008	105,033	56,243	103,018	57,788
2009	104,331	57,928	104,368	57,548
2010	106,262	58,401	113,451	58,359

Source: Quarterly Census of Employment and Wages, 2001-10, author's calculations

Figure 6 charts relative earnings since 2001 for the three industry clusters, each of which experienced rising relative earnings between 2001 and 2010. Relative earnings in the core life sciences industries rose from 1.6 in 2001 to 1.8 in 2010. Similarly, relative earnings in other high tech industries rose from 1.7 to 1.9, and life sciences supporting industries rose from 0.9 to 1.0.

Figure 6: Relative earnings by industry cluster in Massachusetts (2001-10)



Source: Quarterly Census of Employment and Wages, 2001-10, author's calculations

<u>Growing the industry "downstream"</u>

Early stage biotechnology and other life sciences technologies require significant private and public investments. These "upstream" activities require funding and support for research and development efforts and for small company start-ups focused on bringing a product or process to market. Massachusetts is a leading state in this regard as has been well documented (Batelle Technology Partnership Practice, 2010; Milken Institute, 2004). Economic development efforts in Massachusetts focus on supporting upstream activities, but another way for the state to sustain competitive advantage is to grow "downstream" operations. Downstream operations include final clinical trials, pilot production, manufacturing, marketing and sales. Commercializing new products or processes opens up a new set of industrial activities which create new jobs. Manufacturing and clinical research benefits from proximity to a region's upstream activities, but can be located outside of the metropolitan core where land is less expensive. Additional benefits from commercialization for a region include new jobs that increase demand for mid-skilled or entry level workers. In this section, downstream activities are measured by changes in shipments and receipts for manufacturing and changes in the volume of clinical trials.

Shipments

Using the Economic Census, examining shipments in life sciences manufacturing provides insight into the growth in downstream activities for the cluster. Data on shipments is also available for comparison with other high tech manufacturing, namely computer and communications equipment, electronic components and instrument manufacturing. Other research in Massachusetts found that between 1997 and 2002, shipments for life sciences manufacturing had high growth rates compared to other states, but a lower location quotient within the state when compared to the U.S. average (Khatiwada & Sum, 2007).

Shipments in life sciences manufacturing doubled between 1997 and 2007; increasing almost 33 percent in 2002 from 1997 and then increasing 48 percent from 2002 to 2007. Total shipments coming from Massachusetts were close to $15 billion and represented 5 percent of the U.S. total for the industries (Table 5). The gain in shipments for life sciences manufacturing has not been enough to make up for the loss of shipments in other high tech manufacturing. Shipments in these manufacturing industries declined by almost 11 percent between 1997 and 2002 and then declined an additional 22 percent in 2007. The total shipments for high tech were just over $18 billion in 2007, at this point not much greater than the life sciences cluster (Table 6).

Table 5: Massachusetts core life sciences manufacturing industries (1997, 2002, and 2007)

	1997	2002	2007
Shipments ($1,000) ($2007)	$7,582,184	$10,047,048	$14,905,058
Change in Shipments (%)	--	32.5%	48.4%
Shipments/Employee ($1,000)	$279	$323	$450
% of US Total	4.3%	3.9%	5.0%

Table 6: Massachusetts other high tech manufacturing industries (1997, 2002, and 2007)

	1997	2002	2007
Shipments ($1,000) ($2007)	$26,246,655	$23,428,536	$18,271,197
Change in Shipments (%)	--	-10.7%	-22.0%
Shipments/Employee ($1,000)	$272	$349	$374
% of US Total	5.1%	6.4%	5.2%

Source: Economic Census, 1997, 2002, 2007, author's calculations

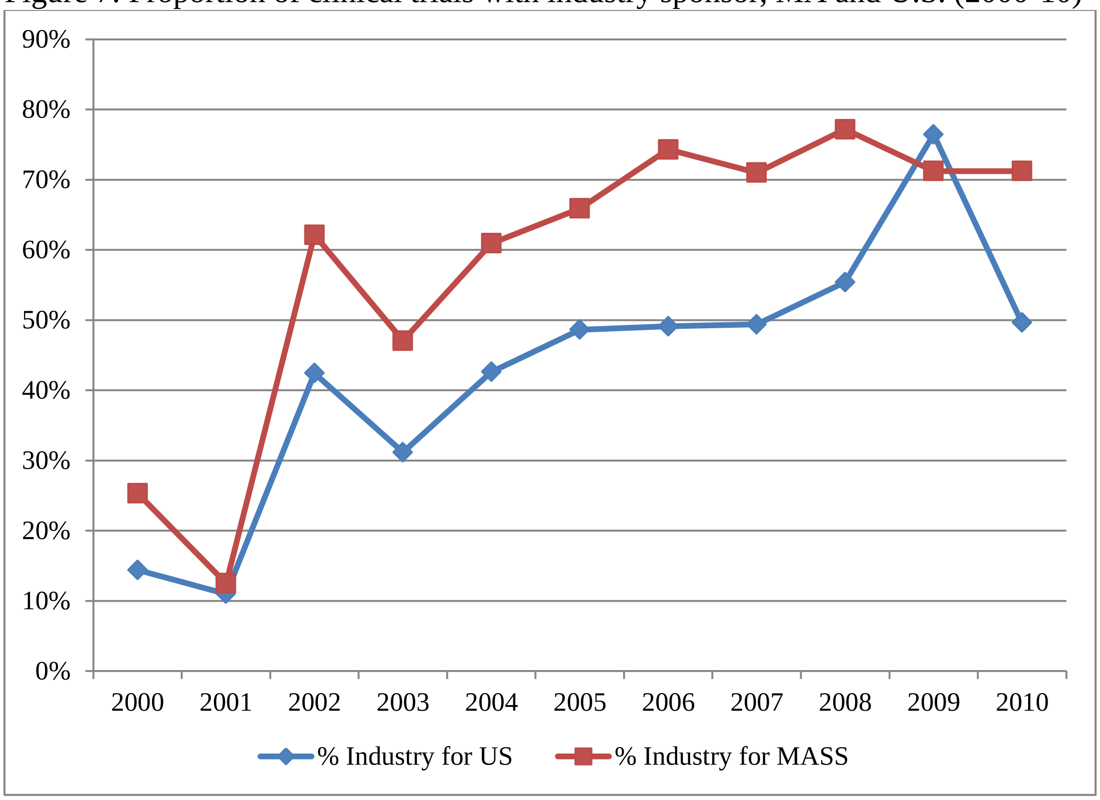
Clinical trials

Clinical trials are usually led by a medical doctor and conducted with human participants during the final phases of drug development under the U.S. Food and Drug Administration. Clinical trials can be sponsored and funded by pharmaceutical companies, medical centers or the government. This section uses clinical trial data from ClinicalTrials.gov for the U.S. and for Massachusetts to look at the extent to which

Massachusetts is a recruitment location for clinical trials, as well as the extent to which industry is sponsoring trials in the state.[6]

For 2000 through 2010, the proportion of industry-sponsored clinical trials to all clinical trials for the U.S. and Massachusetts is shown in Figure 7. This demonstrates the relative importance of industry in generating clinical trials over time. The graph shows that compared to the U.S., a larger proportion of Massachusetts clinical trials were sponsored by industry as opposed to government institutions or universities. On average, 58 percent of clinical trials located in Massachusetts during the decade were sponsored by industry (as compared to 43 percent for all U.S.).

Figure 7: Proportion of clinical trials with industry sponsor, MA and U.S. (2000-10)



Source: ClinicalTrials.gov, author's calculations

[6] A clinical trial was assigned to Massachusetts if there was a recruitment location in the state, which does not necessarily mean that the clinical trial was initiated in Massachusetts.

In Massachusetts, industry-sponsored clinical trials versus clinical trials without an industry sponsor are shown in Figure 8. These are graphed as the percentage of all U.S. clinical trials with an industry sponsor that have a location in Massachusetts (blue line with diamond markers) and the percentage of non-industry sponsored U.S. clinical trials that have a location in Massachusetts (red line with square markers). This figure shows the declining share of clinical trial activity in Massachusetts relative to the U.S. by sponsor type during the 2000s. The relative number of clinical trials in Massachusetts, both industry and non-industry sponsored, trend down between 2000 and 2010. For example, the average percentage of total U.S. industry sponsored clinical trials in Massachusetts between 2000-05 was almost 29 percent. This averaged declined to just under 21 percent for the 2005-10 period (see Table 7). [7]

[7] See M. Porter on clinical trial activity declining because of reluctance or disinterest on the part of the hospital system (Massachusetts Technology Collaborative, 2006).

Figure 8: Industry and non-industry sponsored clinical trials in Massachusetts (2000-10) as % of total U.S.

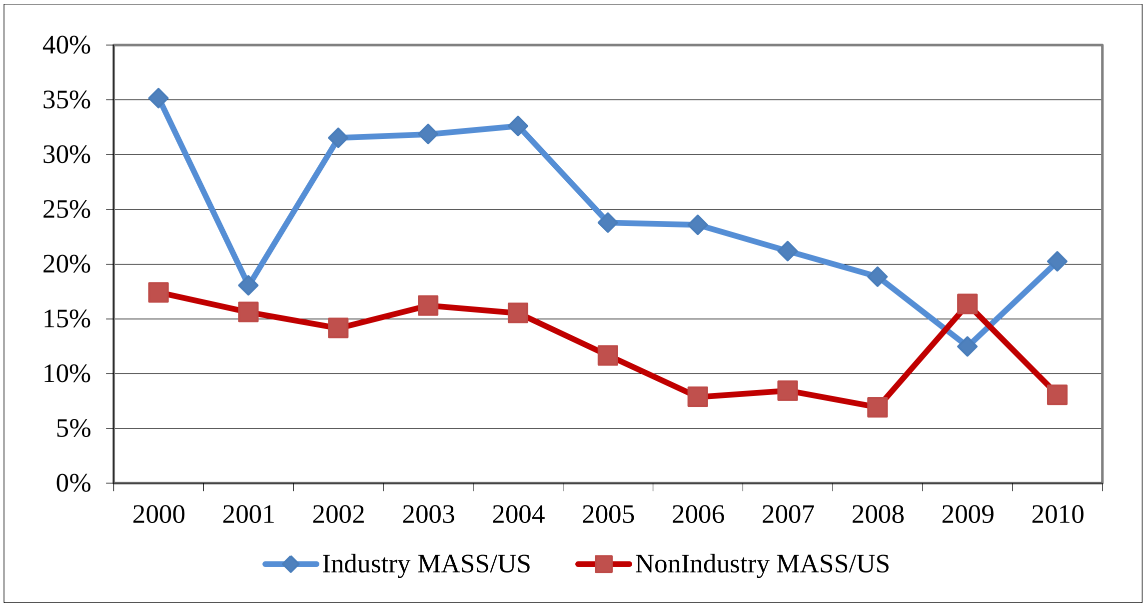


Table 7: Multi-year averages of the proportion of clinical trials for selected ratios

	2000-10	2000-05	2005-10
Total MASS/U.S.	17.3%	19.8%	15.2%
% Industry for U.S.	42.7%	31.7%	53.0%
% Industry for MASS	58.1%	45.6%	69.8%
Industry MASS/U.S.	24.5%	28.8%	20.7%
Non-Industry MASS/U.S.	12.6%	15.1%	10.3%

Source: ClinicalTrials.gov, author's calculations

The distribution of economic gains

This section examines the distribution of growth in the life sciences as it relates to equity. First it looks at earnings inequality broadly across the state and the extent to which the innovation economy contributes to that inequality. Second, it considers the economic development policies and initiatives put into place during the 2000s which were intended to support industry performance, but to also to encourage participation in the industry. In part, this has meant improving access to the industry (or improving equality of opportunity). In turn, this includes helping municipalities and sub-state regions address infrastructure and regulatory issues that support development, particularly in regions that need job growth; developing training programs for blue collar workers to address expected job growth in this area, and building diversity by encouraging women and minorities to pursue STEM careers. Additionally, economic development efforts, especially those that address participation in the life sciences have been more pronounced than in other sectors of the innovation economy. Therefore, when distributional outcomes of the life sciences and other high tech sectors are compared, we would expect to see increased equity measures for the life sciences.

The analysis that follows relies primarily on Public Use Microdata files from the U.S. Census and the American Community Survey to study the distributional change in core life sciences employment during the decade. This includes assessing change in employment by sub-state region, educational attainment, and personal characteristics. Multivariate analysis is used in this section to compare these changes in life sciences employment with other high tech industries (the remaining base of the innovation economy). This comparison uses a multinomial logit model to examine which factors are related to being employed in each sector of the innovation economy and the private sector more broadly. These factors include education, age, gender, race, and location within the state.

Earnings inequality and the innovation economy

As Massachusetts seeks to maintain its competitive advantage in the core life sciences industries, and given the growth in employment and relative earnings, the state might expect to incur an increase in earnings inequality. Sustained competitive advantage in the innovation sectors likely concentrates economic benefits to more prosperous metro regions and higher skilled workers. This section examines the possible impact of growth in the innovation economy on earnings inequality for the state broadly.

In order to address this question, earnings quartiles are calculated using ACS and Census 2000 data for full-time, full year workers. Using 2010 dollars, quartiles are calculated for the innovation economy, total private sector employment, and private sector employment minus the innovation economy (core life sciences and other high tech industries). Table 8 provides the 25th and 75th percentile for each year – 2000, 2005, and 2010. An earnings inequality ratio is also derived dividing the 75th by the 25th percentile.

In the innovation economy only, the earnings inequality ratio has been between 2.16 and 2.32. It is not clear that earnings inequality is growing in those industries. In contrast, regardless of whether we take the impact of the innovation economy into account or not, earnings for the 25th percentile in the private sector decline over the decade from $32,924 in 2000 to $30,000 in 2010. Alternatively, earnings for the 75th percentile rise about 10 percent from $70,913 in 2000 to $77,000 in 2010. Therefore, with or without the innovation economy, earnings inequality grows during the decade. For example, the earnings inequality ratio for all private sector, full-time, full year workers in 2010 was 2.57, up from 2.15 in 2000.

Table 8: Earnings inequality (75th/25th percentiles) by sector (2010 $)

Year	2000	2005	2010
Innovation Economy			
25th	$ 46,853	$ 45,777	$ 48,500
75th	$ 101,304	$ 106,069	$ 105,000
Inequality ratio (75th/25th)	2.16	2.32	2.16
Total Private			
25th	$ 32,924	$ 31,263	$ 30,000
75th	$ 70,913	$ 72,574	$ 77,000
Inequality ratio (75th/25th)	2.15	2.32	2.57
Total Private without Innovation Economy			
25th	$ 32,291	$ 30,146	$ 30,000
75th	$ 67,114	$ 66,991	$ 70,000
Inequality ratio (75th/25th)	2.08	2.22	2.33

Source: American Community Survey, 2005 and 2010, and Census 2000, author's calculations

The innovation economy appears to make little difference in earnings for the bottom quartile, but contributes to higher earnings for the top. For example, in 2010 earnings for the 75th percentile were 10 percent higher due to the inclusion of the innovation economy while earnings for the 25th percentile were flat. The contribution of the innovation economy to higher earnings for the 75th percentile has also increased over time. For example, in 2000 the innovation economy increased earnings for the 75th percentile by 6 percent and then, in 2005, by 8 percent. Overall, it appears that the innovation economy is not solely responsible for increased inequality; however, it is contributing to its magnitude over time.

Regional employment and investment

This section focuses on changes in employment by region to understand whether or not there has been growth outside of the metropolitan core. Knowledge intensive industries, like the life sciences, have been known to concentrate in the metropolitan core and surrounding suburbs. Adjacent regions that may be less populated or less economically prosperous would likely benefit from industry expansion into their regions. These regions may also possess benefits for industry. For example, real estate costs in Massachusetts are lesser the farther out from the Boston-Cambridge core. Outside regions provide an important source of low cost real estate for large operations like manufacturing. Further, this section uses geographic visuals to illustrate how economic development investments correspond with employment growth across the state. These visuals provide an indication of how well policy tools are targeting growth, particularly outside of the Boston-Cambridge core.

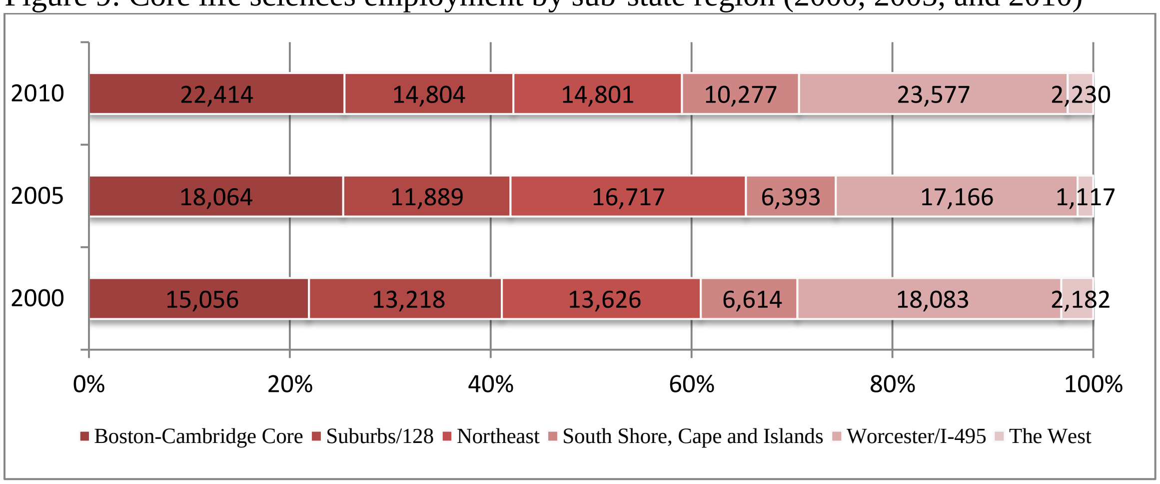
Table 9 provides estimated employment numbers for the core life sciences for 2000, 2005, and 2010 by sub-state region. The margin of error was calculated for both the estimates and the distribution (not shown) to determine statistical significance of changes during the decade. The check marks in Table 9 indicate where statistically significant changes in employment and distribution occur at a 90% confidence interval for the given time period.. Employment in the core life sciences grew from 15,000 to 18,000 between 2000 and 2005 in the Boston-Cambridge core; an increase of about 20 percent. The metro core is the only area in the state that experienced employment growth during this time. In the second half of the decade (2005 to 2010), employment increased again in Boston-

Cambridge, growing beyond 22,000 employees. However, during the second half of the decade, employment also increased in the Worcester – I-495 area and on the South Shore. Core life sciences employment in the Worcester area increased from just over 17,000 in 2005 to 23,500 in 2010 (a 37 percent increase). Employment on the South Shore increased from about 6,000 to 10,000 employees during the last half of the decade. This is a 61 percent increase in employment for the region. Employment estimates for the Northeast region for the three years being measured are not significantly different. Yet, with respect to distribution of employment across the state, the Northeast's share declined from 23 percent in 2005 to 17 percent in 2010. Employment estimates are also depicted in Figure 9. The figure shows the estimated employment counts and distribution across the state.

Table 9: Changes in life sciences employment and distribution of employment for sub-state regions (2000, 2005, and 2010)

Estimated employment	**2000**	**2005**	**2010**	**Change from 2000-05 (sig. 90% CI)**	**Change from 2005-10 (sig. 90% CI)**	**Change from 2000-10 (sig. 90% CI)**
Boston-Cambridge Core	15,056	18,064	22,414	√	√	√
Suburbs/128	13,218	11,889	14,804			
Northeast	13,626	16,717	14,801			
South Shore, Cape and Islands	6,614	6,393	10,277		√	√
Worcester/I-495	18,083	17,166	23,577		√	√
The West	2,182	1,117	2,230	√	√	
Total	68,779	71,346	88,103		√	√
Distribution of employment	**2000**	**2005**	**2010**	**Change from 2000-05 (sig. 90% CI)**	**Change from 2005-10 (sig. 90% CI)**	**Change from 2000-10 (sig. 90% CI)**
Boston-Cambridge Core	21.89%	25.32%	25.44%			
Suburbs/128	19.22%	16.66%	16.80%			
Northeast	19.81%	23.43%	16.80%		√	
South Shore, Cape and Islands	9.62%	8.96%	11.66%			
Worcester/I-495	26.29%	24.06%	26.76%			
The West	3.17%	1.57%	2.53%	√		
Total	100%	100%	100%			

Figure 9: Core life sciences employment by sub-state region (2000, 2005, and 2010)



Source: American Community Survey, 2005 and 2010, and Census 2000, author's calculations

The maps that follow are based on county employment information; which is different from the regions used above. Figure 10 provides a map of Massachusetts and shows employment levels by county for 2010. Middlesex County, which encompasses Cambridge, has the highest employment level (dark blue). Essex County has the next highest level. The counties in Western Massachusetts, the South Shore and Cape and Islands have the lowest levels of life sciences employment. Worcester, Norfolk, and Suffolk Counties have 4,000 to 8,000 life sciences employees each and Bristol County has at least 2,000.

A similar map is used to chart employment growth during the 2000-10 decade. Figure 11 shows that employment growth has been more variable then employment shares during the decade. This means that although some regions have experienced high rates of growth, this has not been enough to affect their employment share relative to regions like Middlesex and Essex Counties. The greatest growth rate (more than 20%) is in Hampden County in the western part of the state. Middlesex, Suffolk and Essex Counties grew as well between 11 and 20%. Worcester, parts of Western Massachusetts, the South Shore and the Cape and Islands experienced some growth; while employment in the life sciences declined in Berkshire, Norfolk and Bristol Counties.

Figure 11 provides the base map for the subsequent three figures. This permits a closer examination of how different policies have targeted different regions that are either growing or declining. First, MassBio’s BioReady campaign rates municipalities by their locational advantage for supporting biotechnology activity across the state. BioReady community endorsements are based on a number of criteria mostly related to local municipal policies that support the development of biotechnology industry operations. Figure 12 overlays the BioReady cities on the employment growth map. There are large clusters of BioReady cities in Middlesex and Essex Counties, but there is a significant spread of cities across the state including in Hampshire, Hampden and Bristol Counties.

The map in Figure 13 exhibits the MLSC tax incentives disbursed between 2008 and 2010. Firms become eligible for a number of tax credits through MLSC in exchange for meeting job creation commitments. The map shows that tax incentives have clustered substantially in Middlesex County while other regions that are growing have not been receiving large tax incentives. There were a few small tax credits awarded in Worcester and Western Massachusetts and a few medium-small credits in the southern counties.

Since 2008, the MLSC has also invested in a number of infrastructure projects across the state, which, were stipulated by the Massachusetts Life Sciences Act in 2008. Designating these projects as priorities was part of the policy making process. Going forward, the MLSC will be using a competitive bidding process to decide on future infrastructure project investments. Importantly, over $100 million was invested in Worcester County infrastructure since 2008.

Figure 10: Life sciences employment levels by county, 2010

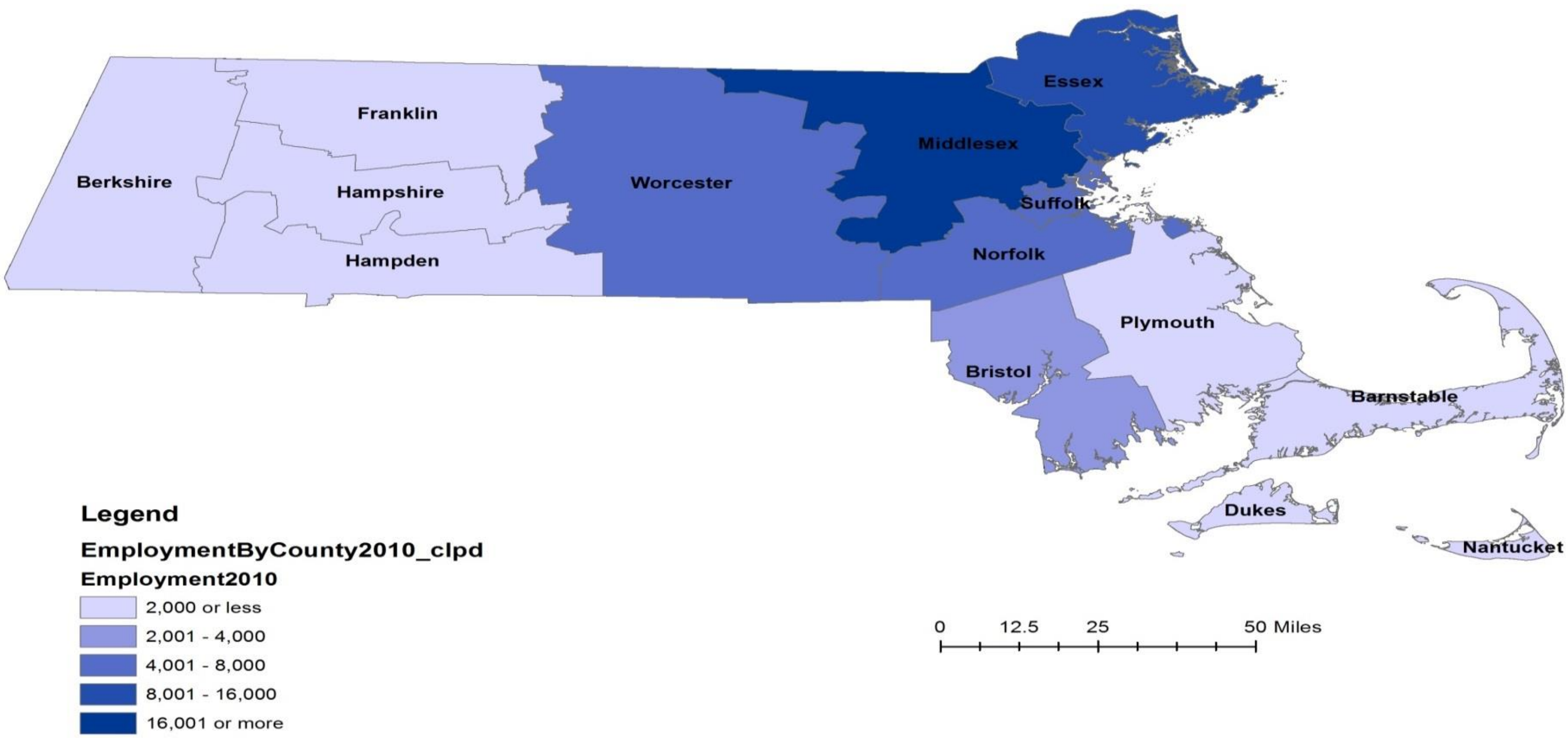


Figure 11: Life sciences employment growth by county, 2000-2010

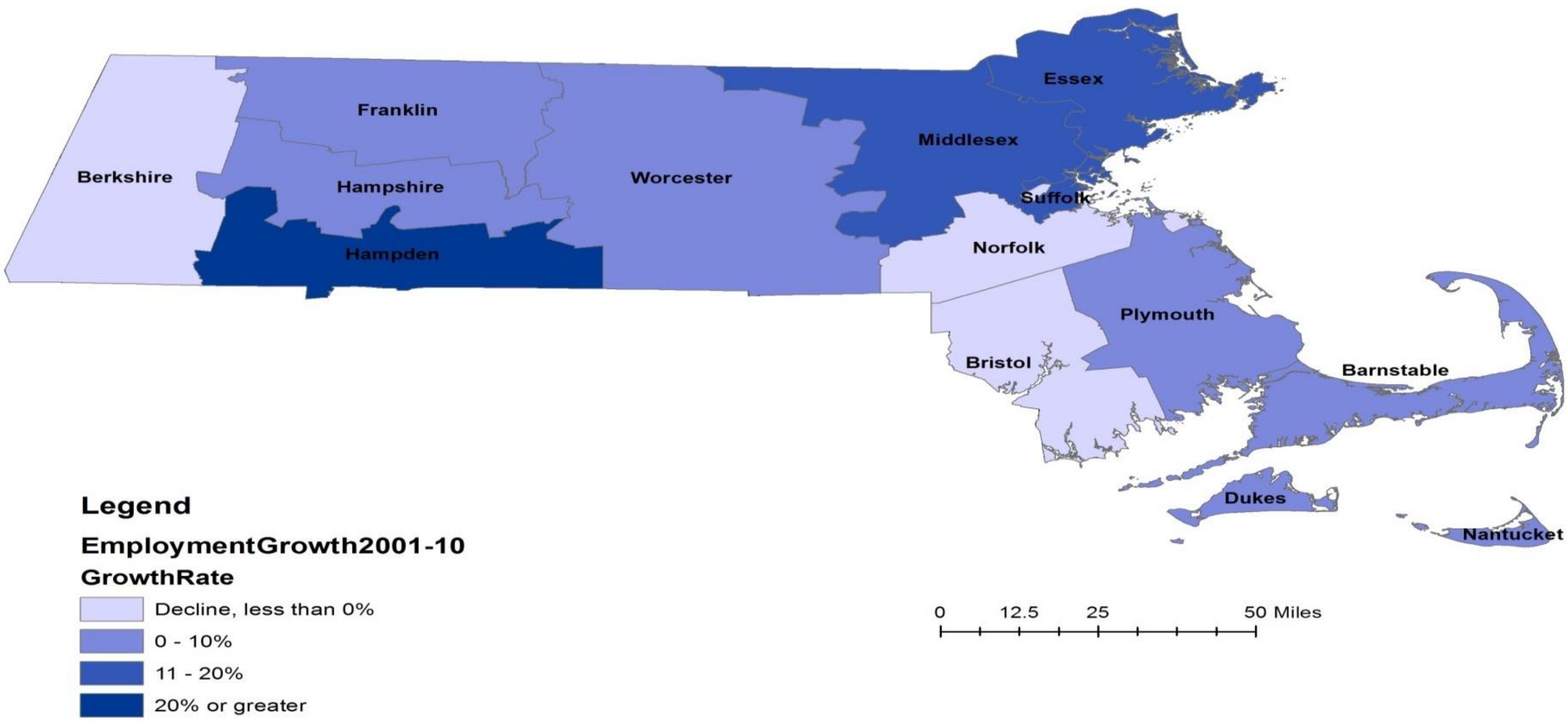


Figure 12: MassBio's BioReady Cities

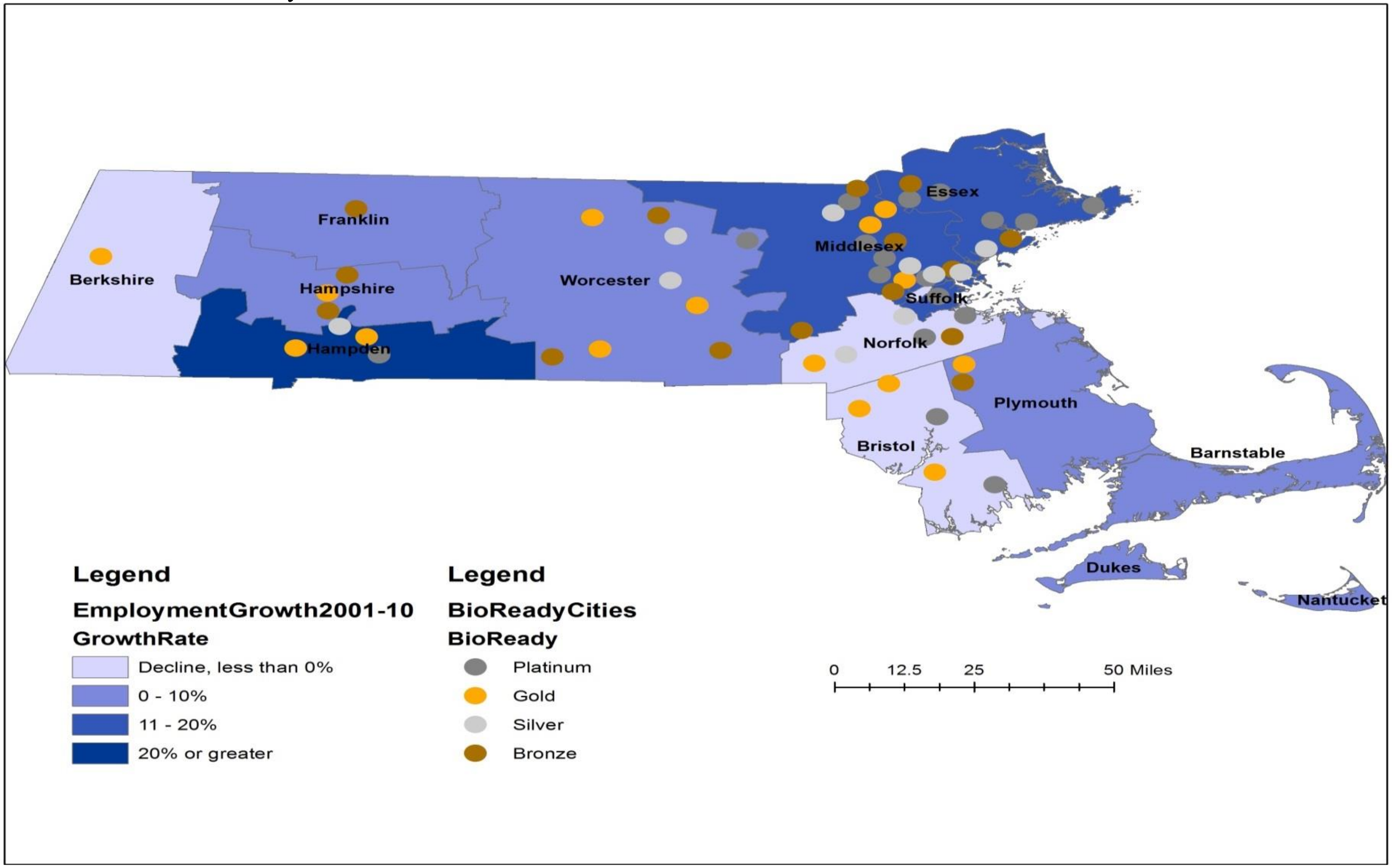


Figure 13: Massachusetts Life Sciences Center tax incentives

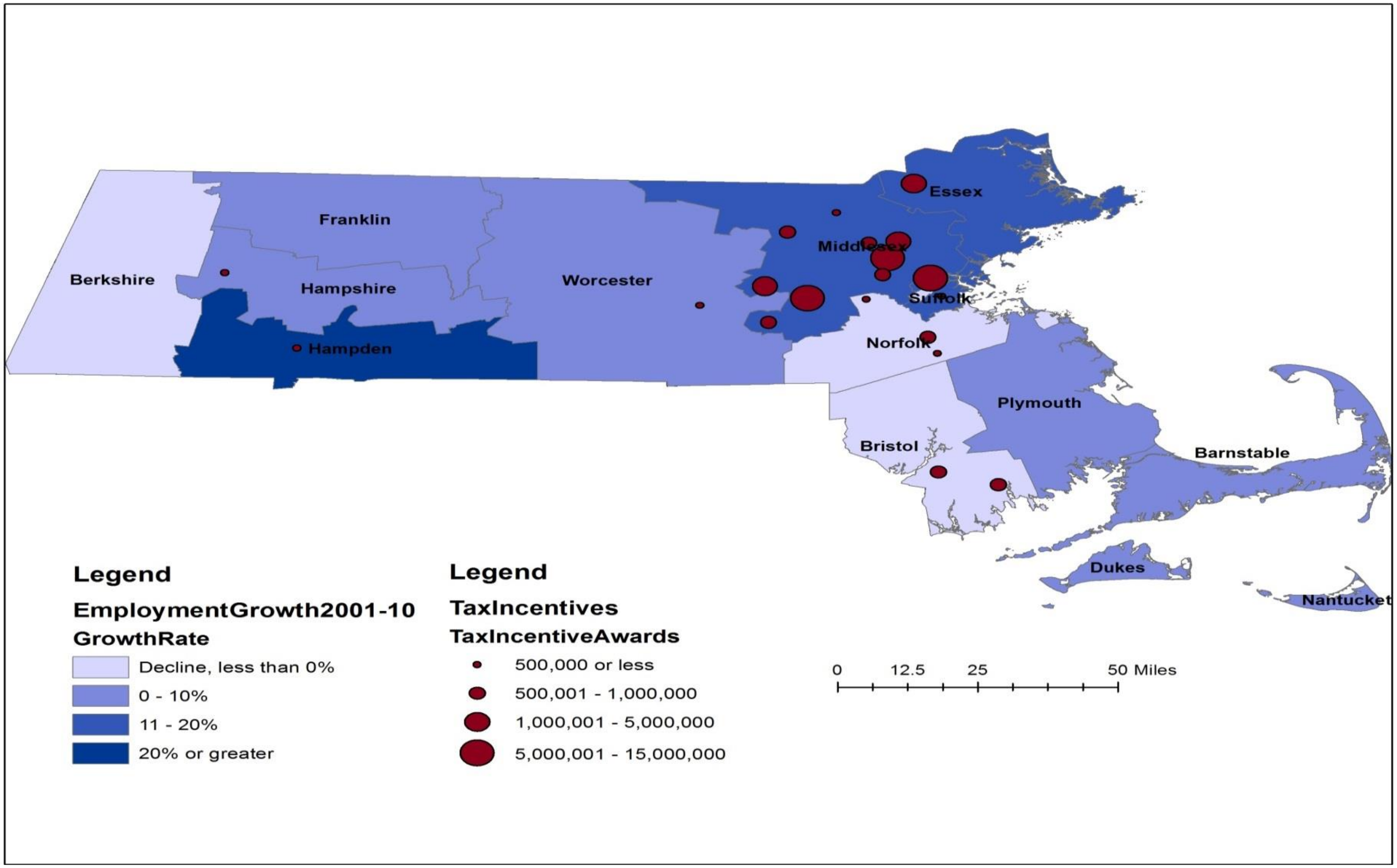
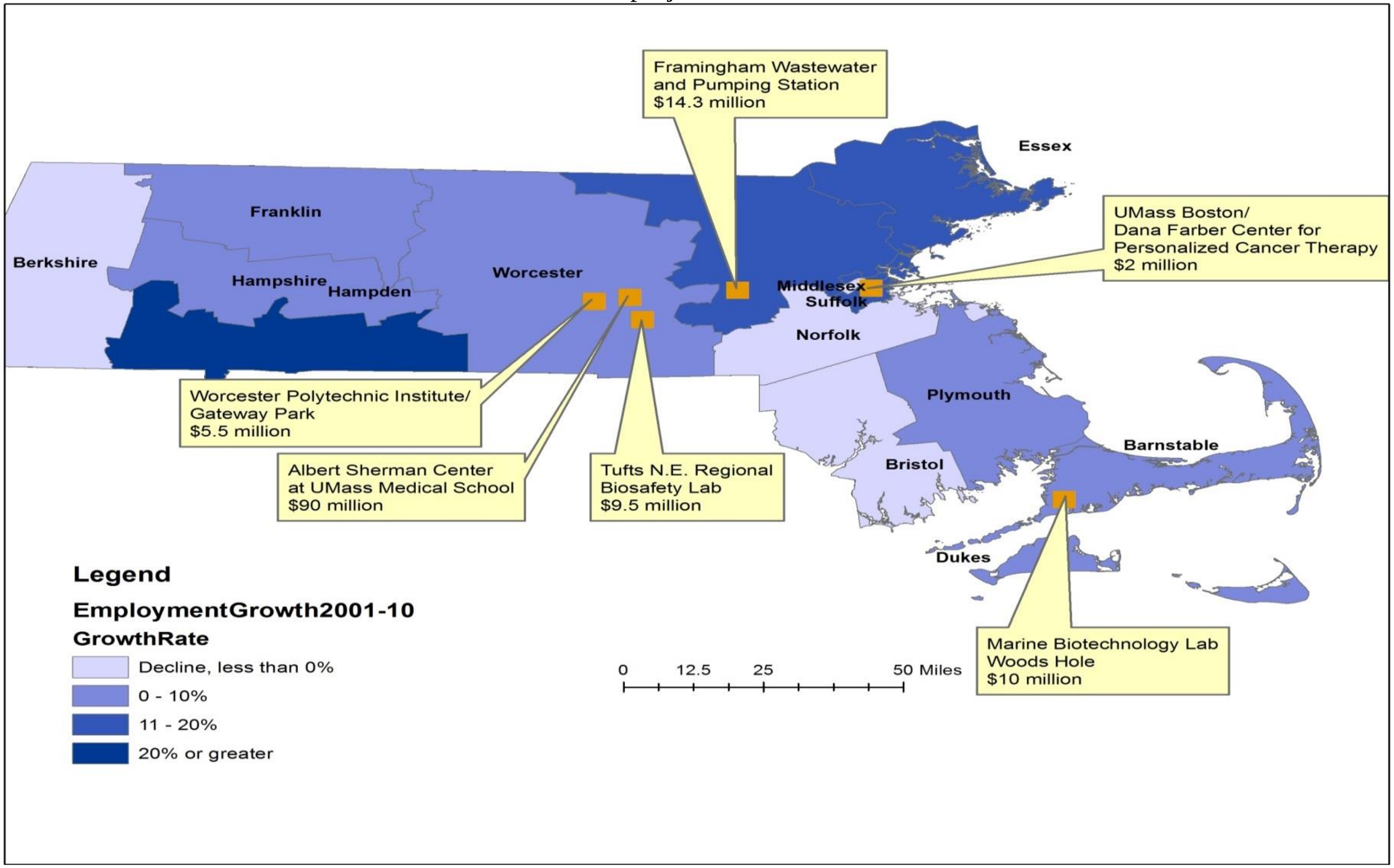


Figure 14: Massachusetts Life Sciences Center infrastructure projects



Workforce diversity

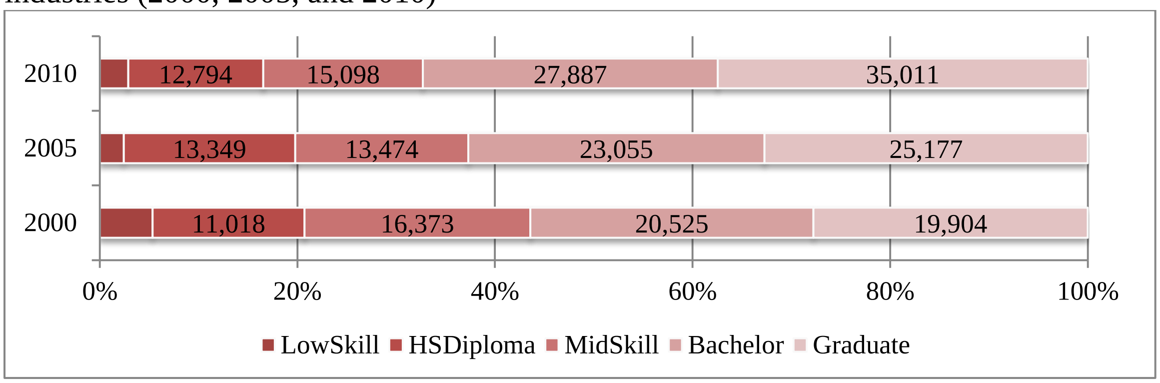
This section measures workforce diversity by looking at several characteristics available in the Census and ACS data. Educational attainment of life sciences workers is examined as a proxy for skill level. The analysis seeks to understand the extent to which mid-skilled workers are employed in the life sciences industries and whether those employment levels have changed during the study period. This is important given the increased involvement of community colleges in providing technical training for the industry as well as understanding the extent to which workers at different skill levels obtain employment in the industry. Second, employment changes are examined with respect to personal characteristics (e.g., race, sex, and nativity) to provide an indication of diversity in the industry. This is an opportunity to show, regardless of equality of opportunity in the industry, how equitable the distribution is within the industry and whether or not it is shifting.

Distribution of educational attainment in core life sciences industries

In 2000, workers with at least a bachelor's degree held 56 percent of jobs in core life sciences industries in Massachusetts. By 2010, this proportion had increased to 67 percent. This increase over the 10-year period was primarily due to increased numbers of workers with graduate degrees. Indeed, increased employment in the core life sciences industry has resulted in economic benefits (e.g., job growth) accruing to high-skilled workers.

Figure 15 provides the distribution of employment by educational attainment. The horizontal axis tracks the percentage of workers in each group and the numbers embedded in the chart provide employment estimates for each of the three years. For mid-skilled workers and workers with only a high school diploma, employment has not expanded during the 2000s. In fact, employment for mid-skilled workers contracted between 2000 and 2005, from about 16,300 workers to 13,400. The estimated employment for mid-skilled workers in 2010 had trended back up to 15,000 workers – however, this change is not statistically significant. Overall, the share of the pie for mid-skilled workers dropped from 23 percent in 2000 to 16 percent in 2010 (see Figure 15).

Figure 15: Distribution of employment by educational attainment for core life sciences industries (2000, 2005, and 2010)



Source: American Community Survey, 2005 and 2010, and Census 2000, author's calculations

Changes in workforce characteristics in the life sciences are also shown in Table 10 and Table 11. These tables provide estimated employment and the distribution of employment in the life sciences by different characteristics. Check marks are used to designate change between the available time periods which is statistically significant at a 90 percent confidence interval.

Table 10: Changes in estimated employment for core life sciences industries by worker characteristic (2000, 2005, and 2010)

Estimated employment	**2000**	**2005**	**2010**	**Change from 2000-05 (sig. 90% CI)**	**Change from 2005-10 (sig. 90% CI)**	**Change from 2000-10 (sig. 90% CI)**
Educational Attainment						
Low Skill	3,839	1,875	2,679	√		√
HS Diploma	11,018	13,349	12,794			
Mid Skill	16,373	13,474	15,098	√		
Bachelor	20,525	23,055	27,887		√	√
Graduate	19,904	25,177	35,011	√	√	√
Age						
16-17	97	86	84			
18-24	5,539	3,007	6,097	√	√	
25-34	17,753	17,843	24,008		√	√
35-54	39,210	43,520	47,270	√		√
55-64	7,765	10,781	13,436	√		√
65+	1,295	1,693	2,574			√
Race/Ethnicity						
White, NH	60,139	60,477	72,413		√	√
Black, NH	1,981	2,913	4,003			√
Asian, NH	5,885	9,254	11,782	√		√
Hispanic	2,509	3,545	3,957			√
Other	1,129	741	1,314			
All Minority	11,520	16,435	21,056	√	√	√
Sex						
Women	29,075	32,357	37,386		√	√
Men	42,584	44,573	56,083		√	√
Other Characteristics						
Foreign Born	14,083	18,304	23,107		√	√
Veteran	8,144	5,853	6,138			√
Total	**71,659**	**76,930**	**93,469**		√	√

Source: American Community Survey, 2005 and 2010, and Census 2000, author's calculations

Table 11: Changes in the distribution of employment for core life sciences industries by worker characteristic (2000, 2005, and 2010)

Estimated employment	**2000**	**2005**	**2010**	**Change from 2000-05 (sig. 90% CI)**	**Change from 2005-10 (sig. 90% CI)**	**Change from 2000-10 (sig. 90% CI)**
Educational Attainment						
Low Skill	5.4%	2.4%	2.9%	√		√
HS Diploma	15.4%	17.4%	13.7%			
Mid Skill	22.8%	17.5%	16.2%	√		√
Bachelor	28.6%	30.0%	29.8%			
Graduate	27.8%	32.7%	37.5%	√		√
Age						
16-17	0.1%	0.1%	0.1%			
18-24	7.7%	3.9%	6.5%	√		
25-34	24.8%	23.2%	25.7%			
35-54	54.7%	56.6%	50.6%		√	√
55-64	10.8%	14.0%	14.4%	√		√
65+	1.8%	2.2%	2.8%			
Race/Ethnicity						
White, NH	83.9%	78.6%	77.5%	√		√
Black, NH	2.8%	3.8%	4.3%			
Asian, NH	8.2%	12.0%	12.6%	√		√
Hispanic	3.5%	4.6%	4.2%			
Other	1.6%	1.0%	1.4%			
All Minority	16.1%	21.4%	22.5%	√		√
Sex						
Women	40.6%	42.1%	40.0%			
Men	59.4%	57.9%	60.0%			
Other Characteristics						
Foreign Born	19.7%	23.8%	24.7%			√
Veteran	11.4%	7.6%	6.6%	√		√

Source: American Community Survey, 2005 and 2010, and Census 2000, author's calculations

Table 10 and Table 11 can be put into context with broader changes in private sector employment during the 2000s. Table 12 provides employment estimates for 2000 and 2010 for the private sector in Massachusetts by worker characteristic and region. Change in the distribution is shown in the right hand column. Between 2000 and 2010, private sector employment grew 3 percent. The life sciences workforce is high skilled because of the large proportion of workers that possess a graduate degree. In the private sector, the proportion of the workforce that was highly educated (holding at least a bachelor's degree) grew. The part of the workforce holding a bachelor's degree increased 17 percent. Workers with graduate degrees increased 28 percent. Workers with a bachelor's degree or higher constituted 34 percent of employment in 2000; rising to 41 percent in 2010 (not shown in the table). There was no change in the size of the private sector workforce that was either mid-skilled or had a high school diploma. The number of low-skilled workers, workers with a high school diploma and mid-skilled workers employed in the private sector declined. These changes in employment by educational attainment in the private sector are similar to the trends in the life sciences.

Table 12: Estimated private sector employment, 2000 and 2010 by worker characteristic and region

Characteristic	Estimated Employment ± MOE						Percent change with 90% CI
	2000			2010			
Skill level							
Low Skill	291,610	±	3,279	201,547	±	9,828	-31%
HS Diploma	603,977	±	4,594	595,003	±	15,988	0%
Mid Skill	698,384	±	4,899	684,923	±	15,826	0%
Bachelor	544,019	±	4,383	633,867	±	13,183	17%
Graduate	303,629	±	3,342	388,085	±	10,936	28%
Sex							
Women	1,189,730	±	5,639	1,244,199	±	16,484	5%
Men	1,251,889	±	5,749	1,259,226	±	12,988	0%
Race/Ethnicity							
White, NH	2,059,099	±	6,760	1,940,585	±	16,028	-6%
Black, NH	100,081	±	1,801	143,968	±	6,736	44%
Asian, NH	94,476	±	1,751	151,926	±	5,007	61%
Hispanic	127,086	±	2,025	211,054	±	7,211	66%
Other	57,527	±	1,370	55,892	±	5,025	0%
Other Characteristic							
Foreign Born	351,555	±	4,959	482,494	±	14,062	37%
Veteran	281,807	±	4,466	141,909	±	6,084	-50%
Sub-state Region							
Boston-Cambridge Core	560,687	±	5,127	610,195	±	13,771	9%
Suburbs/128	358,289	±	4,170	356,485	±	11,418	0%
Northeast	353,001	±	4,141	340,943	±	9,819	0%
South Shore, Cape and Islands	355,808	±	4,156	355,151	±	9,383	0%
Worcester/I-495	418,801	±	4,485	438,328	±	11,457	5%
The West	258,371	±	3,571	246,442	±	7,856	-5%
TOTAL	2,441,619	±	7,608	2,503,425	±	19,953	3%

Source: American Community Survey, 2005 and 2010, and Census 2000, author's calculations

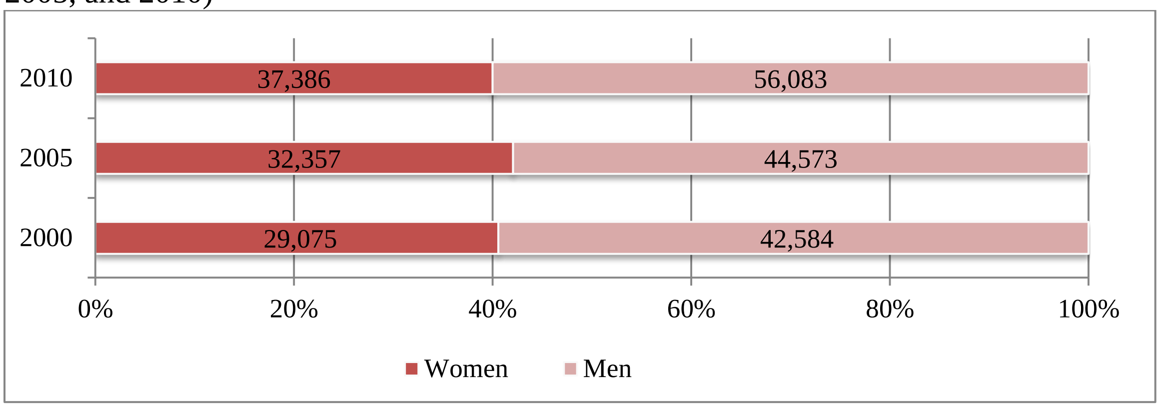
Other worker characteristics

In addition to educational attainment, Table 10 and Table 11 provide detail on employment estimates and the distribution of employment by worker characteristics. These calculations show the number and percentage of jobs by different characteristics.

The three columns on the right hand side have check marks to indicate which changes were statistically significant at a 90 percent confidence interval.

During the 2000s, employment for both men and women has expanded proportionate to total industry employment. However, women are underrepresented relative to the rest of the private sector (see Table 12) in the core life science industries. From 2000 to 2010, women represented about 40 percent of total employment in the life sciences (see Figure 16; Table 10 and Table 11).

Figure 16: Distribution of employment by sex for core life sciences industries (2000, 2005, and 2010)

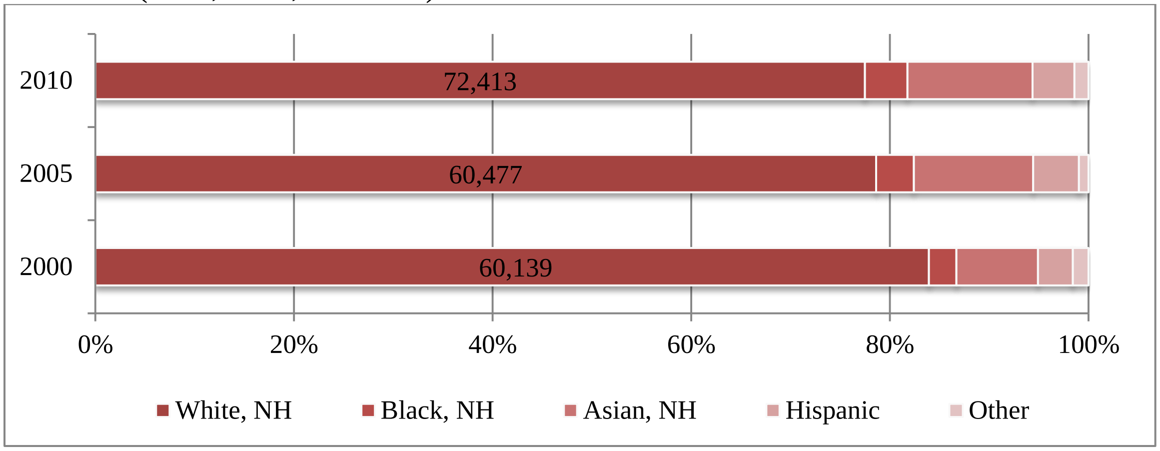


Source: American Community Survey, 2005 and 2010, and Census 2000, author's calculations

Estimated employment for white, non-Hispanic workers in the life sciences held steady between 2000 and 2005 and then expanded between 2005 and 2010. Their share of the workforce dropped during the decade as minority employment grew. In 2000, 84 percent of employment in the core life sciences industries was attributed to white, non-Hispanic workers. By 2010, this proportion had dropped to about 78 percent. Changes in minority employment are largely attributed to an increase in employment for Asian workers within the sector, particularly between 2000 and 2005. Black or African

American and Hispanic workers have seen increased employment in the core life sciences over the course of the decade. Black or African American employment increased from about 2,000 workers in 2000 to just over 4,000 in 2010. Hispanics saw a similar increase. However, neither black or African American or Hispanic workers increased their portion of the pie – as was seen for Asian workers (see Figure 17; Table 10 and Table 11).

Figure 17: Distribution of employment by race and ethnicity for core life sciences industries (2000, 2005, and 2010)



Source: American Community Survey, 2005 and 2010, and Census 2000, author's calculations

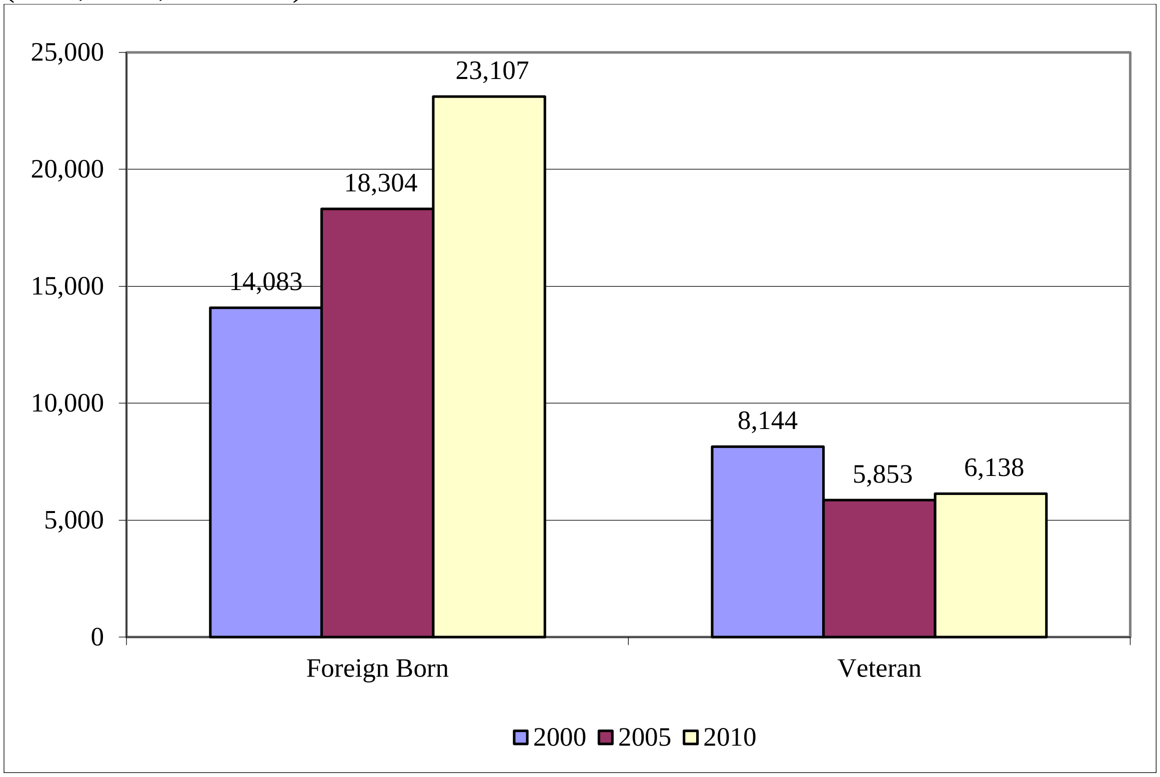
Changes in minority employment in the private sector are more dramatic than those is witnessed in the life sciences. In fact, private sector employment would not have grown if not for minority employment. Black or African American employment in the private sector increased by 44 percent. Asian employment increased by 61 percent and Hispanic employment grew 66 percent (see Table 12).

Two other characteristics that were examined over time using the ACS and Census data were workers who are foreign born and workers who are veterans. Immigrant workers in Massachusetts tend to cluster in high skill jobs and in lower skilled jobs. Other research[8] has shown that workers who are foreign born make up a sizeable portion of the core life sciences workforce. Figure 18 shows change in employment for workers who are foreign born. Employment for foreign-born workers significantly increased between 2005 and 2010 (from 18,000 to 23,000). The proportion of foreign-born workers increased significantly between 2000 and 2010, from 20 percent to 25 percent of the workforce. This increase coincides with an increase in the private sector as a whole (Table 12).

Especially with respect to manufacturing work environments, it is expected that veterans are attractive candidates because they likely possess technical training through their military background. However, employment of veterans declined during the decade. In 2000, they constituted 11 percent of the life sciences workforce and in 2010 this had dropped to less than 7 percent (see also Table 10 and Table 11). This decrease is also mirrored in the private sector (Table 12).

[8] See for example: Monti, D. J., Smith-Doerr, L., & McQuaid, J. (2007). *Immigrant entrepreneurs in the Massachusetts biotechnology industry*. Boston, MA: Immigrant Learning Center, Inc.

Figure 18: Core life sciences employment attributed to foreign born and veteran workers (2000, 2005, and 2010)



Source: American Community Survey, 2005 and 2010, and Census 2000, author's calculations

<u>Changes in industry mix and occupational structure</u>

As mentioned in an earlier section, economic development efforts have focused on increasing downstream operations in the state. This has meant not only working to make the state attractive for manufacturing activity, but also increasing the training programs for mid-skilled workers to meet this new demand. The question remains, however, to what extent have downstream operations grown? One way to examine this is to look at whether or not the industry mix has changed over time and what regions have benefited or not benefited from increased manufacturing activity. It is also possible to look at how occupations have grown and whether or not the state has seen an increase in the number of occupations suitable for mid-skilled workers.

Industry mix

In order to explain employment changes by sub-state region, the Quarterly Census of Employment and Wages (QCEW) is used to look at which of the core industries are found by Metropolitan Statistical Area (MSA) across the state. Figure 19 and Table 13 shows the contribution of each core industry to the MSAs total life sciences employment as of 2010. The industry mix in the Boston-Cambridge core has increasingly concentrated in R&D. In 2001, R&D comprised 63 percent of the cluster's employment. In 2010, 73 percent of life sciences employment in the Boston-Cambridge core was in R&D. The remainder of employment is spread across manufacturing in medical equipment, electro medical and irradiation apparatus manufacturing.

The Worcester MSA, South Coast region and Essex County have greater concentrations of manufacturing than the metro core. For example, manufacturing constitutes about 58 percent of the clusters employment in the Worcester area. Also, during the decade, Worcester added manufacturing activity in electro-medical apparatus. In 2010, neither Springfield nor Pittsfield had any manufacturing activity in the life sciences. In the past, Pittsfield has had some medical equipment manufacturing, but at a low and variable level.

Figure 19: Employment by detailed life sciences industry by sub-state regions, 2010

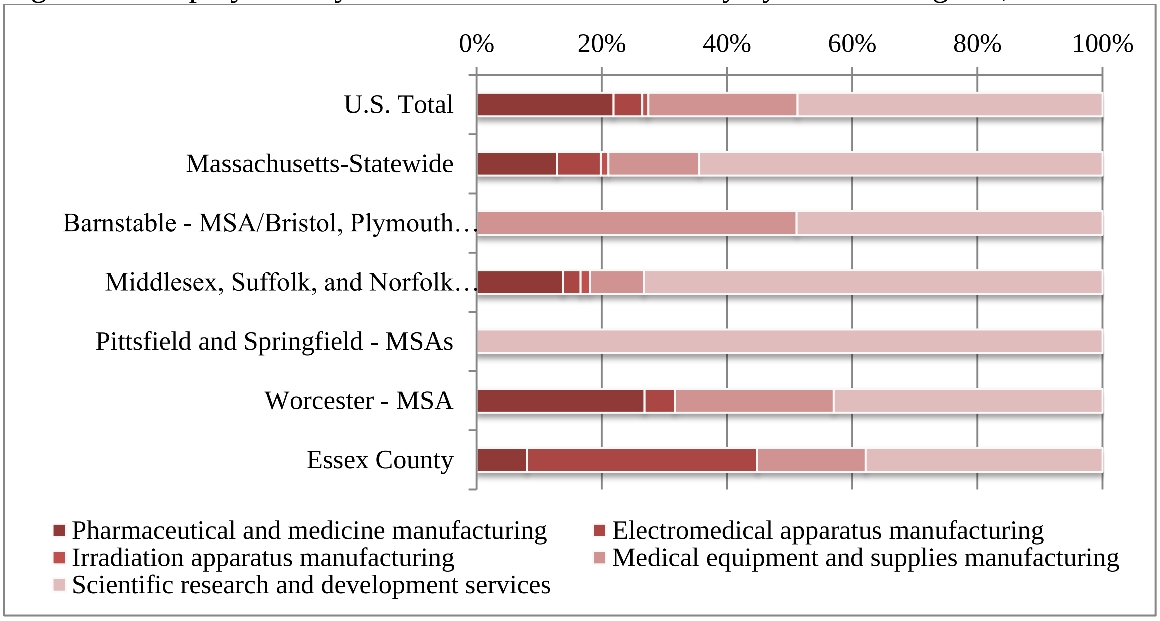


Table 13: Distribution of core life sciences employment by detailed industry for sub-state regions, 2010

	Pharmaceutical and medicine manufacturing	Electromedical apparatus manufacturing	Irradiation apparatus manufacturing	Medical equipment and supplies manufacturing	Scientific research and development services	Total
U.S. Total	22%	5%	1%	24%	49%	100%
Massachusetts-Statewide	13%	7%	1%	15%	64%	100%
Barnstable - MSA/Bristol, Plymouth Counties	0%	0%	0%	51%	49%	100%
Middlesex, Suffolk, and Norfolk Counties	14%	3%	1%	9%	73%	100%
Pittsfield and Springfield - MSAs	0%	0%	0%	0%	100%	100%
Worcester - MSA	27%	5%	0%	25%	43%	100%
Essex County	8%	37%	0%	17%	38%	100%

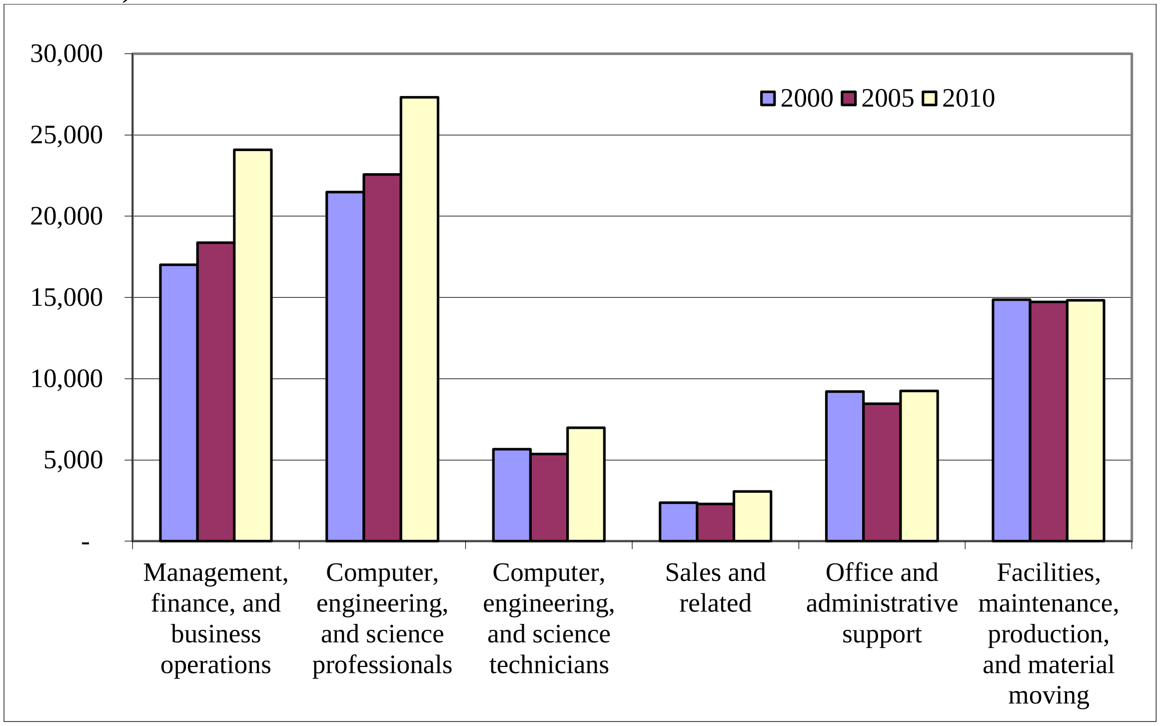
Source: Quarterly Census of Employment and Wages, 2001-10, author's calculations

Occupational structure

There are six occupations within the core life sciences industries that comprise about 95 percent of its total employment. These are depicted in Figure 20 and include management, finance and business operations; science, technology, engineering and mathematics (STEM) professionals; STEM technicians; sales; office and administrative support; and facilities, production, and material moving. The remaining occupations found in the core life sciences include building services, medical professionals, health care support staff and legal professionals and support staff. Industry analysis (Grillo, 2007a, 2007b) shows that increased downstream activity in the state's industry would result in an increase in jobs related to clinical research, regulatory affairs, operations, and sales and marketing. Further, this growth has the potential to increase demand for entry-level and mid-skilled workers in the industry.

Entry-level or mid-skill jobs require some previous industry experience (usually gained through an internship) and include STEM technicians like clinical data management, laboratory assistants, and animal technicians. These jobs also include production and facilities positions like manufacturing technicians and associates, environmental technicians, and material handlers. According to Figure 20, occupational growth in the past decade has concentrated in management, finance and business, and STEM professionals. Further, growth in management and STEM professionals has intensified during the second half of the decade when compared to earlier years. No growth, from a statistically significant perspective, is observed for STEM technicians or facilities and production personnel, or for sales and office staff.

Figure 20: Employment in the core life sciences industries by occupation (2000, 2005, and 2010)



Source: American Community Survey, 2005 and 2010, and Census 2000, author's calculations

Comparison of core life sciences and high tech industry employment with respect to equitable outcomes – multivariate analysis

The core life sciences industries are known to provide jobs to a large portion of highly skilled workers. This means there are fewer opportunities for blue collar or mid-skilled workers available within the industry as compared to the private sector more broadly. The high skilled nature of the industry also means by extension that there will likely be gender, race and ethnic differentials when compared to the private sector as whole because some groups in society are underrepresented or overrepresented at higher levels of educational attainment. Furthermore, knowledge-intensive industries that cluster around a metropolitan core often do not extend beyond the suburbs to less populated or less prosperous regions within the state. With this in mind, high tech industry employment is used as a comparison with life sciences to account for these significant differences within the innovation economy (not just with the private sector in general). Similar to life sciences, the high tech cluster in Massachusetts contains a mix of manufacturing and high-skilled services and is considered an important component of the state's economy.

This section seeks to answer the question: To what extent, if at all, has the Massachusetts' core life sciences industry contributed to more equitable outcomes with respect to sub-state regional growth and workforce diversity when compared to the rest of the innovation economy?

The multinomial logit model

Outcomes for the two industry clusters are compared using a multinomial logit model. The model is designed to examine what factors help predict employment in the core life sciences and high tech industries relative to each other and to the rest of the private sector. A multinomial logit design is used to address the unordered, qualitative dependent variable representing three possible outcomes: employment in the life sciences core industry cluster, employment in the high tech industry cluster, or employment in other industries in the private sector. The dependent variable meets the assumption of independence from irrelevant alternatives in that employment in each of the specified sectors of the economy is discrete. Based on Liao (1994), the logit form of the equation is:

$$\log\,[\text{Prob}(y=j) \,/\, \text{Prob}(y=J)] = \sum_{k=1}^{K} \beta_{jk} x_k$$

The dependent variable (y) is a dummy variable with the three possible outcomes (j). The unit of observation is the individual. The three possible outcomes are being employed in the life sciences, being employed in other high tech industries in the innovation economy, and being employed in another industry in the private sector. In a logit model, the dependent variable is calculated as a logged ratio of two probabilities. For example, the probability that y equals the outcome of being employed in the life sciences is divided by the probability that y equals being employed in other industries in the private sector. The ratio for the dependent variable is logged to ensure that outcomes fall within the range of 0 and 1. The explanatory variables (x) include those already described in an earlier section: educational attainment, age, sub-state region, and personal characteristics (gender, race/ethnicity, foreign born and veteran) (see Table 10 and Table 11). In the equation, K equals the number of observations and β equals the vector of coefficients.

All explanatory variables are qualitative in nature and are treated as dummies in the logit model. Corresponding reference variables for the model are workers with graduate degrees, prime age workers 35-54 years old, the Boston-Cambridge Core, male, white non-Hispanic, native born and non-veteran. There is no explanatory variable for industry size. Industry size is accounted for in the logit function as the denominator in the ratio of two probabilities.

The data source used is the 2000 Census and the 2005 and 2010 one-year estimates of the American Community Survey. These data were analyzed using Stata. Multinomial logit models were run for each of the three years using weights and provide a comparison of the factors that help predict employment outcomes by industry cluster. The number of observations for each year is listed in

Table 14. In particular, it provides a comparison between employment in life sciences and high tech industries.

Table 14: Observations available for analysis in the Census 2000 and American Community Survey data sets

	Census 2000	ACS 2005	ACS 2010
# of individuals employed in the private sector	104,005	19,744	20,245
# of individuals employed in the life sciences industries	3,492	799	969
# of individuals employed in other high tech industries	6,930	1,615	1,550

Interpretation of results

The tables that follow provide a summary of the output based on three different comparisons: 1) being employed in the life sciences industry versus being employed in other industries in the private sector (Table 15), 2) being employed in other high tech industries versus being employed in other industries in the private sector (Table 16), and 3) being employed in the life sciences industries versus being employed in other high tech industries (Table 17). The tables provide the list of explanatory variables with the exception of the reference variables. The table contains output for the three years being studied which are 2000, 2005, and 2010. The coefficients for each year are in the first three columns. These coefficients are logged and difficult to interpret, at least beyond showing the sign and significance of the variable. Therefore, the relative risk ratios (or odds ratios) are calculated for explanatory variables that are significant. The relative risk ratio (RRR) is calculated by exponentiating the coefficient. RRRs are reported in the last three columns of the table for each year being studied. The RRRs can be interpreted as the odds of an event relative to the reference or comparison group which is easier to understand than the coefficients in the output.

For example, Table 15 shows that in 2010 the odds for mid-skilled workers to be employed in the core life sciences industries when compared to the rest of the private sector are only 0.23 times as high as the same odds for workers holding a graduate degree. Further, the relative risk ratio for mid-skilled workers has fallen from 0.48 in 2000. In other words the odds for a mid-skilled worker to be employed in the life sciences have declined by more than half. Alternatively, in 2010, the odds for someone working in the Worcester I-495 region to be employed in the core life science industries was more than two and a quarter times as high as the same odds for someone working in the Boston-Cambridge core. This indicates a strong concentration of life sciences employment in Central Massachusetts relative to other employment in the private sector, for that region especially when compared to the Boston-Cambridge core.

Additionally, Table 16 provides a summary of output for a comparison of other high tech industries and the private sector. We see some similar results. The odds for being employed as a mid-skilled worker have declined over time in other high tech industries. The odds for being employed in other high tech in the Worcester region in 2010 are three times higher than that for the Boston-Cambridge core.

Table 15: Factors influencing employment in the core life sciences industries versus the rest of the private sector (2000, 2005 and 2010)

Variables	Coefficients						RRR		
	2000		2005		2010		2000	2005	2010
Low skill	-1.25	***	-2.35	***	-1.79	***	0.29	0.10	0.17
HS diploma	-1.06	***	-1.29	***	-1.60	***	0.35	0.27	0.20
Mid skill	-0.74	***	-1.26	***	-1.49	***	0.48	0.28	0.23
Bachelor	-0.34	***	-0.50	***	-0.74	***	0.71	0.60	0.48
Suburbs 128	0.43	***	0.23		0.37	***	1.54		1.45
Northeast	0.50	***	0.82	***	0.57	***	1.65	2.28	1.76
South coast	-0.17	**	-0.17		0.24		0.84		
Worcester 495	0.65	***	0.57	***	0.81	***	1.92	1.78	2.26
The West	-0.98	***	-1.61	***	-1.02	***	0.38	0.20	0.36
Age 16 to 17	-2.13	***	-1.14		-1.68		0.12		
Age 18 to 24	-0.28	***	-0.96	***	-0.46	**	0.75	0.38	0.63
Age 25 to 34	-0.07		-0.26	**	-0.04			0.77	
Age 55 to 64	-0.07		-0.03		-0.21	*			0.81
Age 65 plus	-0.56	***	-0.68	***	-0.62	**	0.57	0.51	0.54
Female	-0.36	***	-0.33	***	-0.51	***	0.70	0.72	0.60
Black, NH	-0.26	**	-0.25		-0.17		0.77		
Asian, NH	0.49	***	0.65	***	0.48	***	1.63	1.91	1.61
Other race, NH	-0.29	*	-0.33		-0.47		0.75		
Hispanic	-0.21	*	-0.20		-0.55	**	0.81		0.58
Foreign	0.39	***	0.21		0.30	**	1.48		1.35
Veteran	-0.04		0.04		0.28	*			1.32
Constant	-3.10	***	-2.46	***	-2.29	***			

*p-value<0.10, ** p-value<0.05, *** p-value<0.01

Source: American Community Survey, 2005 and 2010, and Census 2000, author's calculations

Table 16: Factors influencing employment in other high tech industries versus the rest of the private sector (2000, 2005 and 2010)

Variables	Coefficients						RRR		
	2000		2005		2010		2000	2005	2010
Low skill	-2.27	***	-2.31	***	-2.32	***	0.10	0.10	0.10
HS diploma	-1.29	***	-1.61	***	-1.68	***	0.27	0.20	0.19
Mid skill	-0.46	***	-0.91	***	-0.96	***	0.63	0.40	0.38
Bachelor	0.19	***	-0.07		0.03		1.21		
Suburbs 128	0.27	***	0.63	***	0.58	***	1.31	1.87	1.78
Northeast	0.40	***	1.49	***	1.03	***	1.49	4.42	2.80
South coast	-0.70	***	0.07		0.09		0.50		
Worcester 495	0.47	***	1.12	***	1.09	***	1.60	3.07	2.96
The West	-0.91	***	-0.38	**	-0.14		0.40	0.69	
Age 16 to 17	-0.51		-0.73		-1.45				
Age 18 to 24	-0.11	**	-0.71	***	-0.96	***	0.89	0.49	0.38
Age 25 to 34	0.16	***	-0.05		-0.18	**	1.18		0.83
Age 55 to 64	-0.38	***	-0.21	**	-0.24	***	0.69	0.81	0.79
Age 65 plus	-0.56	***	-0.89	***	-0.56	***	0.57	0.41	0.57
Female	-0.79	***	-0.84	***	-1.05	***	0.45	0.43	0.35
Black, NH	-0.55	***	-0.59	**	-0.63	**	0.58	0.56	0.53
Asian, NH	0.53	***	0.62	***	0.85	***	1.70	1.87	2.35
Other race, NH	-0.16		-0.36		0.14				
Hispanic	-0.54	***	-0.35		-0.35	*	0.58		0.71
Foreign	0.22	***	0.43	***	0.24	**	1.24	1.54	1.27
Veteran	-0.10	**	0.21	*	0.24	*	0.90	1.23	1.27
Constant	-2.35	***	-2.26	***	-2.17	***			

*p-value<0.10, ** p-value<0.05, *** p-value<0.01

Source: American Community Survey, 2005 and 2010, and Census 2000, author's calculations

Table 17: Factors influencing employment in the core life sciences versus other high tech industries (2000, 2005 and 2010)

Variables	**Coefficients**			**RRR**		
	2000	**2005**	**2010**	**2000**	**2005**	**2010**
Low skill	1.01 ***	-0.04	0.53	2.75		
HS diploma	0.23 ***	0.31	0.08	1.26		
Mid skill	-0.29 ***	-0.35 **	-0.52 ***	0.75	0.70	0.59
Bachelor	-0.53 ***	-0.43 ***	-0.77 ***	0.59	0.65	0.46
Suburbs 128	0.17 **	-0.39 **	-0.21	1.18	0.67	
Northeast	0.10	-0.66 ***	-0.46 ***		0.52	0.63
South coast	0.52 ***	-0.24	0.15	1.69		
Worcester 495	0.18 ***	-0.55 ***	-0.27 *	1.20	0.58	0.76
The West	-0.07	-1.24 ***	-0.88 ***		0.29	0.42
Age 16 to 17	-1.62 ***	-0.41	-0.23	0.20		
Age 18 to 24	-0.17 *	-0.26	0.50 **	0.84		1.64
Age 25 to 34	-0.23 ***	-0.20	0.15	0.79		
Age 55 to 64	0.31 ***	0.18	0.03	1.37		
Age 65 plus	0.01	0.21	-0.07			
Female	0.43 ***	0.51 ***	0.54 ***	1.53	1.67	1.71
Black, NH	0.29 *	0.34	0.46	1.33		
Asian, NH	-0.04	0.02	-0.38 **			0.69
Other race, NH	-0.13	0.03	-0.61			
Hispanic	0.33 **	0.15	-0.20	1.39		
Foreign	0.17 **	-0.22	0.06	1.19		
Veteran	0.07	-0.17	0.04			
Constant	-0.74 ***	-0.20	-0.12			

*p-value<0.10, ** p-value<0.05, *** p-value<0.01

Source: American Community Survey, 2005 and 2010, and Census 2000, author's calculations

The comparison between the innovation economy industries and the private sector yielded fairly predictable outcomes. The innovation economy has more demand for higher skilled workers, while minorities (especially Hispanic and African American or black) and women are less likely to be represented in the innovation economy than other private sector industries. There is also similarities overtime. The odds for mid-skilled workers to be employed in the innovation economy have declined between 2000 and 2010. This is true for both the life sciences and other high tech industries. Also, the odds of being employed in other regions outside the Boston-Cambridge core (especially Worcester I-495) have increased for workers in the innovation economy. Therefore, of particular interest to this case study are the odds for being employed in the core life sciences compared with other sectors in the innovation economy.

The results of the multinomial logit (see Table 17) show that relative risk ratios for mid-skilled workers (as well as workers with a bachelor's degree) are lower for core life sciences when compared to high tech industries. In 2010, the odds for mid-skilled workers to be employed in the life sciences cluster when compared to other high tech industries was only 0.59 times as high as the same odds for workers with graduate degrees. Again, the relative risk ratios have fallen since 2000. This outcome implies fewer and declining opportunities for mid-skilled workers in the innovation economy broadly and specifically in the core life sciences. It is also worth noting that workers with a bachelor degree have low odds of being employed in the life sciences compared to other high tech industries. This output implies that the life sciences have a much higher demand for workers with graduate degrees than other sectors in the innovation economy.

With respect to diversity in worker characteristics, there are some interesting results, particularly for women and minority workers. In 2010, the odds for a woman to be employed in the life sciences cluster relative to men were 1.71 times as high when compared to high tech industries. In terms of the field of science, women are more likely to be represented in biology than in computer science and the output here supports that. In 2000, coefficients for black or African American and Hispanic relative to non-Hispanic white workers and foreign born workers relative to native born were positive and significant. This resulted in higher relative risk ratios for these three groups when compared to high tech industries; however in the latter two years (2005 and 2010) these coefficients were not significant.

Predicted probabilities are another way to help interpret the results of the logit model. Predicted probabilities help illustrate different cases depending on the explanatory variables. For example, it is possible to calculate the predicted probability for mid-skilled workers while holding other variables at their means. The predicted probabilities for being employed in the two main industry clusters for the innovation economy for 2000, 2005, and 2010 are below. Predicted probabilities were calculated for each explanatory variable while holding the remaining variables at their mean.

Table 18: Predicted probabilities calculated for selected variables (2000, 2005 and 2010)

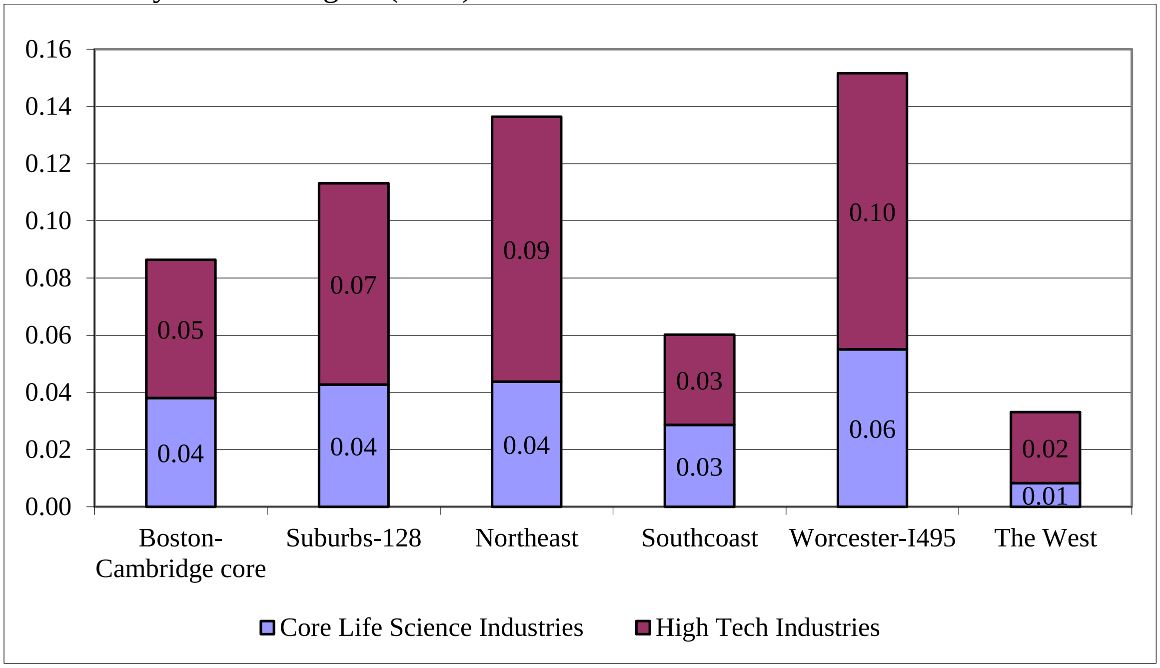
Variable	2000	2005	2010	Variable	2000	2005	2010
Any worker				***Women***			
Core Life Sciences	0.023	0.034	0.039	Core Life Sciences	0.019	0.029	0.030
Other High Tech	0.044	0.069	0.064	Other High Tech	0.029	0.039	0.034
HS Diploma				***Men***			
Core Life Sciences	0.015	0.020	0.020	Core Life Sciences	0.027	0.040	0.049
Other High Tech	0.018	0.028	0.023	Other High Tech	0.058	0.099	0.094
Mid-skilled				***Boston-Cambridge core***			
Core Life Sciences	0.019	0.022	0.020	Core Life Sciences	0.022	0.038	0.042
Other High Tech	0.039	0.051	0.040	Other High Tech	0.049	0.048	0.048
Bachelor's degree				***Suburbs-128***			
Core Life Sciences	0.030	0.045	0.047	Core Life Sciences	0.031	0.039	0.043
Other High Tech	0.082	0.114	0.107	Other High Tech	0.057	0.076	0.076
Graduate degree				***Northeast***			
Core Life Sciences	0.044	0.074	0.089	Core Life Sciences	0.031	0.050	0.046
Other High Tech	0.069	0.122	0.108	Other High Tech	0.060	0.130	0.099
White, non-Hispanic				***South coast***			
Core Life Sciences	0.023	0.034	0.038	Core Life Sciences	0.014	0.022	0.025
Other High Tech	0.045	0.068	0.063	Other High Tech	0.018	0.030	0.031
Black, non-Hispanic				***Worcester-I495***			
Core Life Sciences	0.017	0.020	0.024	Core Life Sciences	0.034	0.046	0.058
Other High Tech	0.022	0.028	0.023	Other High Tech	0.062	0.108	0.099
Asian				***The West***			
Core Life Sciences	0.053	0.076	0.091	Core Life Sciences	0.007	0.004	0.010
Other High Tech	0.099	0.170	0.149	Other High Tech	0.015	0.022	0.027
Hispanic							
Core Life Sciences	0.017	0.021	0.020				
Other High Tech	0.020	0.039	0.033				

Source: American Community Survey, 2005 and 2010, and Census 2000, author's calculations

Overall, the probability of any worker being employed in the core life sciences grew from 2.3 percent to 3.9 percent between 2000 and 2010. The probability of any worker being employed in the high tech industries increased between 2000 and 2005 (4.4 percent and 6.9 percent) and then dropped a little to 6.4 percent in 2010. For the high tech industries, declining probabilities are observed across the board by worker characteristic and most regions; whereas, the core life sciences had increasing probabilities for most worker characteristics and most of the regions measured by the model. However, for the life sciences cluster the increased probability of being employed in the life sciences did not benefit all groups measured in the model; namely, mid-skilled workers and Hispanic workers. Mid-skilled workers and Hispanic workers saw declining probabilities in the core life sciences between 2005 and 2010.

With respect to sub-state regions, there are some variations in outcomes for The West and the South coast regions, but these are the regions with the smaller number of observations as well as the least amount of activity and therefore require more caution in drawing conclusions from. The Northeast region, however, has absorbed more volatility than any other region, particularly with respect to high tech industries. By 2010, the Worcester I-495 region showed the greatest concentration of predicted employment in the state – almost 6 percent in core life science industries and 10 percent in high tech (Figure 21).

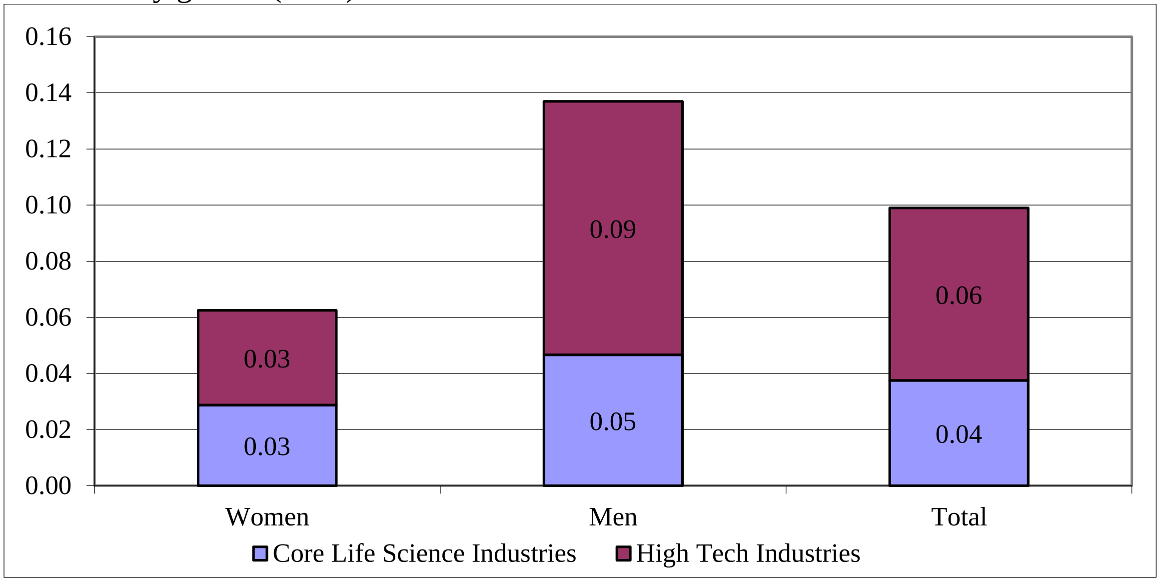
Figure 21: Predicted probabilities of being employed in the life sciences and high tech industries by sub-state region (2010)



Source: American Community Survey, 2005 and 2010, and Census 2000, author's calculations

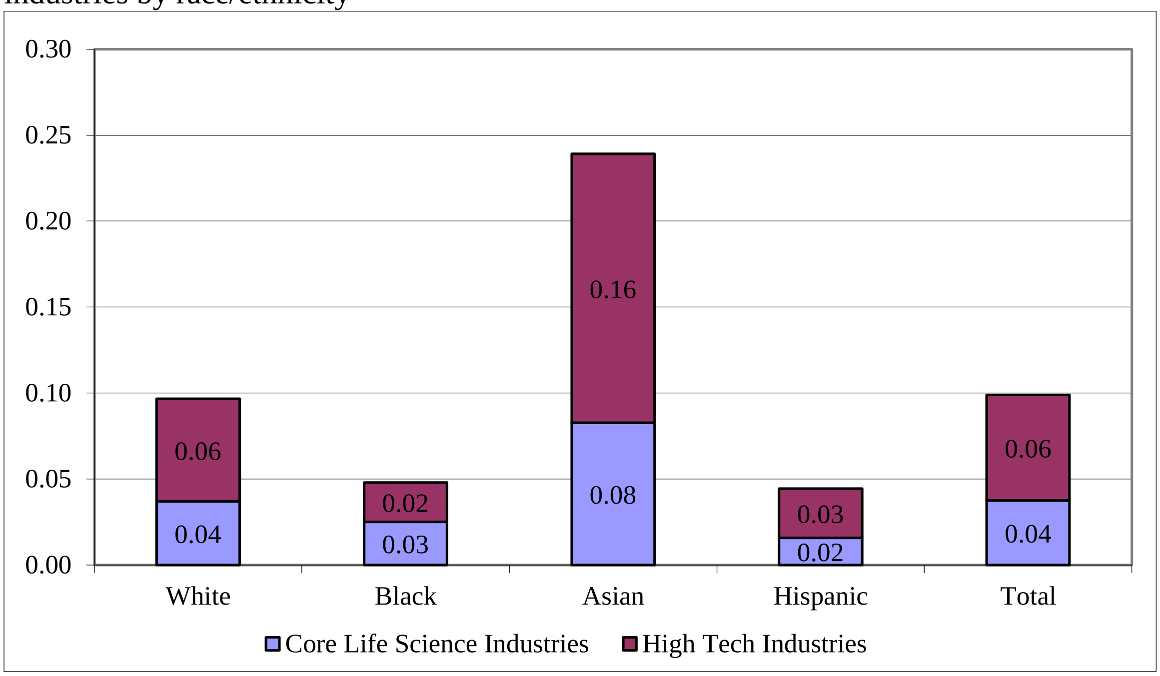
Lastly, the multinomial logit results suggest that although women and minority workers are underrepresented in both the life sciences and high tech industries, they have fared better in the life sciences – with respect to accessing employment opportunities. There could be a number of reasons why this is. Perhaps women and minorities are more attracted to fields related biology rather than computer science or the manner in which the industries are organized or the types of occupations available. For 2010, Figure 22 and Figure 23 provide the predicted probabilities for being employed by industry cluster for women and minorities. In particular for women and black or African American workers, the predicted probabilities for being employed in either life sciences or high tech are equal despite the fact that high tech employment is two-thirds larger than that of the core life sciences (3 percent for women, 2 percent for black or African American).

Figure 22: Predicted probabilities of being employed in the life sciences and high tech industries by gender (2010)



Source: American Community Survey, 2005 and 2010, and Census 2000, author's calculations

Figure 23: Predicted probabilities of being employed in the life sciences and high tech industries by race/ethnicity



Source: American Community Survey, 2005 and 2010, and Census 2000, author's calculations

Stakeholder Perspectives on regional competitiveness, the distribution of economic gains and the trajectory of economic development

In summary, the evaluation of economic and labor market outcomes shows that Massachusetts has sustained its competitive advantage in the core life sciences industries. This competitive advantage is driven by research and development services and a highly skilled workforce. By 2010, efforts to expand the state's competitive advantage to downstream activities has had mixed results. The state has seen some increase in manufacturing activities (e.g., as measured by shipments). There are regions outside of the Boston-Cambridge core that have benefited from this, namely the Worcester I-495 area. There is, however, little evidence that industry growth coupled with increased efforts on the part of development intermediaries and community colleges have provided benefits to workers with less than a bachelor's degree (at least so far). Indeed, the role of mid-skilled workers across the Massachusetts innovation economy has diminished during the decade. Lastly, women and particular minority groups (especially black or African American and Hispanic workers) are underrepresented in the innovation economy, but have had greater access to employment in the core life sciences when compared to other high tech industries.

Given this context, how do various stakeholders evaluate the economic development policies and initiatives in the life sciences? This section draws on qualitative data[9] to answer the following questions:

- What are stakeholder views on industry outlook and regional competitiveness – particularly with respect to downstream operations?
- How do stakeholders view the objectives of economic development policies and initiatives with respect to both efficiency and equity?
- How have employers engaged in regional economic development initiatives and what have they gained?

<u>Regional competitiveness, industry outlook and downstream operations</u>

Across the board stakeholders hold an optimistic outlook for the industry and convey a general sense of pride in what the industry has accomplished in the state and its position in the global economy. For example, one stakeholder described the Massachusetts life sciences this way:

- *Massachusetts is a global starting place…. We've cultivated expertise, not only do we have great scientists; we have great business managers…. [A company might grow up] in Massachusetts, but for the sake of business health needs to be closer to markets everywhere – this [global] expansion helps Massachusetts too. (Development Intermediary, 2011)*

The development intermediaries have continued to focus on issues related to increasing manufacturing activity and encouraging location and expansion in regions

[9] The qualitative data for this section includes: semi-structured interviews conducted in 2010 and 2011 with four employers and three development intermediaries; a summary report I authored for the Massachusetts Workforce Board Association based on interviews I conducted in 2009 with three additional employers and two educational providers; notes from attending a number of industry events between 2008-11; discussions with a few key informants; and organizational documents.

across the state with the view that more needs to be done. Massachusetts is well positioned to take a lead in early stage manufacturing and process innovation, but it is not clear to stakeholders that the region has achieved its goal.

- *The manufacturing base in Massachusetts is impressive. We're at least in the top 10. We have important assets and are a strong competitor on the biologics side. (Development Intermediary, 2011)*
- *[There is a] growing interest in biologics manufacturing by traditional pharmaceutical companies…. These companies are viewing the development of biologics as part of their future…. [The industry has seen] lots of merger and acquisition activity to chase after that part of the market…. Massachusetts has benefited a great deal from this activity – in terms of jobs and investment in the state. (Development Intermediary, 2011)*
- *[Central Massachusetts] has all the components…to be a top notch cluster - academia, industry, hospitals, and research. WPI and UMass play an important role. (Employer, 2009)*

Development intermediaries and educational providers are looking for ways to improve on what is being done to address access to jobs for a greater range of workers – particularly Massachusetts residents, women, minorities, and first generation college students. For example, the Massachusetts Life Sciences Center (MLSC) is focused on the community college system and internships, as well as building the manufacturing base across the state.

- *Massachusetts has a well-skilled workforce which is an important component in terms of driving success…but we're not sitting on our laurels. Workforce development is one priority…not just science degrees or doctorates, "strong skills" are needed in every part of value chain. (Development Intermediary, 2010)*
- *We want a well-distributed workforce and we want employers to know how to find them…make it easy to match-make. (Development Intermediary, 2010)*
- *[We're] looking across the state [in supporting industry], not just Boston or Cambridge…. Manufacturing can be done in other parts of the state…. We want*

biomanufacturing jobs to stay in the state, but they're not necessarily going to be done in Cambridge or Boston. (Development Intermediary, 2010)

The views of development intermediaries regarding the future include expecting to see the industry mature and observing employers becoming more concerned with operational efficiencies (not just innovation) which will impact how firms organize their workforce and where they choose to locate within the state. Development intermediaries, educators and employers reason that the increased growth in recent years, despite the recession, will spur additional growth in the future.

- *East Cambridge and Boston space is at a premium. Companies take it if it makes strategic sense to be located in the hub…. As a company matures, maybe they go public, they have commercial ready products – then companies start making decisions about costs. They start looking to Route 128 and I-495 and the different places you can be for space at a lesser cost. (Development Intermediary, 2011)*
- *We have the workforce in the short term, but if in fact we see an explosion in activity – in new technology and products, it will put strain on workforce needs again. [In the long term], you need the pool of people. (Development Intermediary, 2011)*

<u>Perspectives on the mid-skilled workforce and leveraging efficiency for equity</u>

Interviews with development intermediaries conducted in 2010 and 2011 in part focused on a set of particular policy objectives addressing workforce development. This includes the Internship Challenge and the equipment and supplies grants offered through the Massachusetts Life Science Center and the Massachusetts Life Sciences Education Consortium facilitated by the Massachusetts Biotechnology Education Foundation. These policy objectives are included in an earlier description in CHAPTER 3 and are detailed in APPENDIX A. Development intermediaries have a firm grasp on the competitive position of the life sciences industry, its economic importance, and its innovative capacity to improve quality of life – from both a health and wealth perspective. However, interviewees were simultaneously concerned about workforce diversity and the economic outlook for the state as a whole. There is recognition on the part of the interviewees that the culture of science and its translation to industry, while receiving public support and generating new wealth, can be perceived as exclusionary. Stakeholders address equity issues in the implementation of policy and initiatives, most often this comes in the form of improving access to the industry (e.g., increasing equality of opportunity). For example, connecting industry to the community college system was a priority for the MLSC's Internship Challenge and the Massachusetts Life Science Education Consortium (MLSEC).

The Internship Challenge facilitates access to jobs for students and new entrants. Internships build industry experience for new entrants, interns learn their way around a company, get hands-on experience with equipment, learn about both the business and science sides of an operation, and move up on the learning curve. In addition to concrete skill development, the Internship Challenge provides a paid work experience, encourages peer networking among interns, and mentoring relationships with industry professionals. The MLSC can shape the Internship Challenge to help ensure an equitable distribution of opportunities across the state. For example, the Internship Challenge has targeted stipends to community college and vocational schools with the hope of improving diversity. In fact, the Internship Challenge increased the representation of Latino and African Americans among interns from 2009 to 2010. Also, the Center is interested in looking at ways to train non-traditional workers and to re-skill displaced workers

(Massachusetts Biotechnology Education Foundation, 2008b; Massachusetts Life Sciences Center, 2009, 2010; Windham-Bannister & Mudawar, 2010).

- *[We're] targeting stipends to community college and vocational schools. These education programs include students who can't afford to go to 4-year programs; these [internship] programs also hold a disproportionately higher share of diverse students…. What can we do to get a diverse pool of workers training for life science jobs and how do we help employers find these workers? (Development Intermediary, 2010)*

Overall, the participation of community college students has been low with respect to the Internship Challenge. The demand for mid-skilled workers through the Internship Challenge may be limited because only small and medium sized firms are eligible for the wage subsidy through the program. Small and medium sized firms (at least the ones focused on research and development) have less demand for community college students as compared to larger firms with manufacturing operations. The equipment and supplies grant program was implemented with the express interest of building educational capacity for the mid-skilled workforce in the life sciences industries and address the drawback in the Internship Challenge. It is intended to benefit students who are training (or being retrained) to work as laboratory and biomanufacturing technicians through community college and vocational programs. The launch of this new program is expected to be in alignment with increased commercial activity in the state (which increases the demand for technicians) and a possible shift in hiring strategies among some employers which would increase the demand for mid-skilled workers. The program is also a response to the concerns of workforce development stakeholders that the life sciences industry needs to create more pathways to jobs for mid-skilled workers.

As a third-party, MBEF is well positioned to facilitate links between industry and education. Part of MBEF's mission is to use collective resources to encourage collaboration across industry stakeholders and *contributing to the sum of its parts*. The MLSEC is intended to improve information with respect to employer hiring and training needs. Prior to the formation of the consortium, community college biotechnology programs had engaged industry employers, but engagement was limited to one-off relationships. Participation in the MLSEC has increased industry contact with community colleges and commitments to on-going efforts to build industry support (Hartford, 2010).

- *Employers do not really understand what the institutions [of higher education] are turning out. [Employers reported] low confidence in the system… (Development Intermediary, 2010)*
- *We're in a time now when industry is looking how to be more efficient and more conscious of expenses related to drug development…. The community college programs are providing more training on the machines… [and community college graduates are important] when concerned about the longevity of the employee. (Development Intermediary, 2010)*
- *When companies work with community college graduates, we know [those workers] stay in Massachusetts. (Development Intermediary, 2010)*

Additionally, the consortium has created a venue for faculty to network across schools, augmenting professional development efforts and has become viewed by some stakeholders as taking on a role that a professional association might provide for the program graduates. In September 2011, MBEF announced that they had received a $150,000 grant from The Boston Foundation to support the consortium, develop connections to industry employers, and build on professional development activities for faculty at the community colleges (Hartford, 2010; Massachusetts Biotechnology Education Foundation, 2011).

Development intermediaries have leveraged policies and initiatives that support industry expansion to also position themselves to assist with labor market planning and coordination. Within the particular contexts of each of their organizations, they are learning how to provide planning and coordination services that firms value and simultaneously encourage workforce diversity and development in regions outside the metropolitan core. The internal evaluations on these efforts have shown positive results, but the interviews pointed to some concerns, namely:

- Participation in the Internship Challenge by community college students is very low. This is a valued service with respect to placing bachelor and graduate degree students, but has been challenging to match mid-skilled students. This is likely related to limiting eligibility for wage subsidies to smaller companies who have less of a demand for technical workers.
- The MLSEC has had some success with employer involvement, but would benefit from increased employer engagement related to training entry-level workers.

Employers have choices in how they hire and develop their entry-level workforce

There are a number of mid-skilled and entry-level job types in the life sciences, particularly related to downstream operations. These are in addition to business support positions in clerical or IT functions, which are less numerous and have been less of a focus in workforce and economic development initiatives. Targeted jobs are related to laboratory and manufacturing support at the technician level. In laboratory environments these include technicians, animal technicians, and data management. In manufacturing environments, these jobs include production, facilities, and environmental technicians; some quality control, documentation, and quality assurance.

The extent to which these jobs are represented in a company's workforce mix depends on the type of company. They are most prominent in large employers, contract manufacturers and contract research organizations. For example, one employer – a large multinational – estimated that 25 percent of its Massachusetts workforce was employed in these positions. A medium sized contract manufacturer estimated that about 75 percent of its workforce had a bachelor's degree or less whereas a small contract research organization had very few entry-level, mid-skilled jobs (Employer Interviews, 2011).

In interviews with employers, there was very little concern expressed about a shortage of qualified candidates for these jobs. However, they know that they are not drawing from a large pool.

- *There are more candidates now than before…we are generally getting enough people, but could use better quality. (Employer, 2009)*
- *The state is a leader in generating a qualified and educated workforce, we need to maintain it. (Employer, 2011)*
- *The market has been pretty good for hiring at the technical level…people could always be better. We can often find people for the job, but we know we are not pulling from a large pool. (Employer, 2009)*

One employer who was in the process of opening a new facility has attracted and hired workers employed at other companies in the area. This type of poaching created some strain on the pipeline in the immediate term (Holgate, 2009). It is also indicative of a very consistent requirement across employers that "entry-level" workers have some industry experience.

- *People coming from different industries might come from work environments where corner cutting is easier, less costly, and more tolerable. We need industry experience – meaning at least pharmaceutical manufacturing if not biopharm…. Workers coming from industries with higher accidents are not sufficiently trained to work in this environment. (Employer, 2009)*

Beyond a technician position, there is little opportunity to advance in life sciences companies without a four-year degree. Manufacturing technicians are usually graded and interviewees report that someone will work and train for two or three years to learn all the processes and advance through those grades. For workers with a bachelor’s degree, there are opportunities in clinical research as well as regulatory affairs with respect to documentation and QA. Within manufacturing, there are process development and engineering positions that require a four-year degree and some years of industry experience. This has meant that for some entry-level workers with a bachelor’s degree, it is possible to take a technician position for two years, build industry experience and then advance, either within the company or elsewhere (Employer Interviews, 2009 and 2011).

- *After the 90 day period from first hired, people are active in the work environment, but it takes 2 or 3 years for technicians [entry-level/mid-skilled worker] to qualify for all the processes…. Two or three years is a long time to get someone trained across the different processes, it's expensive to lose people too early. (Employer, 2011)*

- *[I]t is a stretch for operators to move into supervisory positions because of the degree requirements. And the work requirements don’t match with the skill set held by an operator. (Employer, 2009)*

- *Operators do move up through four grades that are non-supervisory… [but] there are not opportunities for operators to move into supervisory positions. Operators perceive a lack of opportunity. (Employer, 2009)*

- *A bachelor's degree is more transferable…someone can move from a technician position to the microbiology department or to QA. (Employer, 2011)*

Interviews with employers revealed a number of consistent standards in the structure of entry-level technical positions regardless of company type or management style and preferences. Most of these are described above and include requiring industry experience for technicians, estimates of 2 to 3 years of on the job training for technicians to be fully proficient in all processes of the operation, advancement beyond a technician or operator position required at least a 4-year degree, and all employers interviewed provided employees with educational benefits. There was far more variability across employers with respect to whom they hired and how they hired them. In part this variability is attributable to company type and size, but it is also a product of management preference.

Some companies, especially small and medium sized firms, showed a preference for hiring entry-level workers with bachelor degrees. Because of this strategy, some companies experience high turnover in their technician positions. New entrants use the technician positions to get their foot in the door and then move to the research side of the operation. One example of a solution for this problem comes from a contract manufacturer. By instituting more formal HR systems[10] and incorporating behavioral interviewing, the company was able to lower its turnover. The company maintained a preference for hiring technicians with bachelor degrees, but improved its ability to screen for individuals who are a good match for the operations side. Thereby, a new entrant with a bachelor's degree can work through the technician grades in two or three years and be

[10] See (Finegold & Frenkel, 2006) on biotechnology and HR systems

ready to transfer into QA, process development, or other positions within the company or with a new company (Employer, 2011).

- *For manufacturing technicians, we like to hire people with bachelor's degrees, but the flip side of doing that is they don't stay as long. People use that position as a stepping stone or to get a foot in the door. (Employer, 2011)*
- *A typical manufacturing worker is blue collar – but we operate at a new level of importance [within the company] – we are currently filling our operating positions with individuals who are degreed –through WPI for example, or MWCC – individuals [who] are skilled and knowledgeable about the basics. (Employer, 2009)*
- *[From the operator's position] the workforce is highly educated…a new facility requires new skills…requires problems solving skills. (Employer, 2009)*

A larger employer may take exception to this strategy. For example, one employer suggested that there was a period of time when *"everyone you touched had to have a bachelor's degree"* for entry-level positions. This resulted in poor job matches in that the aspirations of the individual did not match the nature of the job. Instead of "over hiring" or "staffing up," this employer reported that mid-skilled workers or high school graduates stayed on longer with the company, were more prepared to work in the manufacturing environment, contributed to workforce diversity, and were still able to build a career (advance) through employer provided educational benefits if they desired (Employer, 2011).

- *There was a period of time when everyone you touched had to have a bachelor's degree…the aspirations of the individual didn't match the job. [It's possible to align] the job requirements with the diversity of the workforce…. Good partnerships at various levels are important - we don't need to staff up - plus you have [mid-skilled workers] for longer. (Employer, 2011)*

- *The educational minimum for entry-level operators is a high school diploma or equal and no experience. However, we don't usually hire someone at that level. Operators usually come in at the next level – high school diploma with one year of experience in biopharm production. (Employer, 2009)*

Employers use a variety of strategies for recruiting entry-level workers. These strategies depend on the type of company, the size of the company, the extent of their demand and management preferences. Employers attend job fairs; connect with schools in their area; and post on company websites and online job boards. All employers interviewed use staffing services to some extent (Employer Interviews, 2011; Holgate, 2009). Smaller employers limit their use of staffing services to harder to fill positions (e.g. sales) and rely on Monster.com and Craig's List to recruit entry-level candidates. Large employers use staffing services to build their entry-level workforce. Staffing services provide these employers with their main pipeline of new workers. Workers are usually hired on temporary status for six to eight months. This allows the employer to screen candidates before committing additional training dollars and provides flexibility in when and how many people they are able to convert to full time positions. There is a difference among large employers who have a national contract with a staffing service and large employers who use multiple staffing services. Namely, with national contracts, all new hires must go through the designated staffing company. Whereas, employers that use multiple services are also able to engage with educational programs to provide internships for students as part of their entry-level hiring strategy. Staffing services pose a challenge for educational programs. In those employers using national contracts it leaves educators to figure out how to either circumvent or leverage those services which has proven difficult to do (Employer, 2011; Holgate, 2009).

- *Our recruitment strategies include working with colleges and attending career fairs…we recruit mostly locally for operators, [whereas] we recruit from all parts of the country for other positions. (Employer, 2009)*
- *We only hire temporary workers for entry level…. People can transition at the end of that initial period of time. Hiring people is costly. Talent acquisition is centralized [at headquarters]; we don't have people on site doing HR… [we use a] preferred [staffing] vendor. (Employer, 2009)*
- *We do a lot of temp-to-perm…a lot. But I try to have diversity. For that I use Minuteman and Middlesex. (Employer, 2011)*

All the employers interviewed described the importance of being engaged in educational initiatives related to science and how this fit with the company's perspective on corporate social responsibility. Many of these employers are engaged in educational initiatives that expand beyond the focus area of this case study – these initiatives extend beyond Massachusetts, include K-12, or focus on professional development for scientists. The MBEF Job Shadow Days for young students provides one relevant example. Employers are enthusiastic about the program and happy to support it. However, employers do not usually report direct benefits for participating in educational initiatives and they mostly focus on how the education system needs to be accountable to industry.

- *The purpose of collaborating [with a community college] is to have a college develop the expertise to provide us with the right kind of talent. (Employer, 2009)*
- *Training needs to meet the needs of industry. These are tough economic times. We'll see what happens in about 6 months, but the [community college] program is off to a good start. (Employer, 2009)*

- *The communication between industry and education is important - letting education know what industry needs. (Employer, 2011)*
- *The business is contributing to [the community college program], but can't say we're getting anything out of it. (Employer, 2011)*

Employers who engage in initiatives for reciprocity and mutual benefit expect them to yield benefits in terms of meeting training needs and improving recruitment and hiring in the firm. These employers also engage at a planning and coordination level. Organizations and collaborations draw on employer expertise to design and improve programs and contribute to planning. Benefits for employers are often understood to be long term: better conditions for the industry and region as a whole. For organizations and collaborations, employer engagement is viewed as essential for program success and coordinating efforts across the region.

- *Community college programs for associate's and certificates are great. Having those programs cuts down on the learning curve for a technician. (Employer, 2011)*
- *[Industry] need[s] to be involved in science education and workforce training, and it's trickier than you think to align across different institutions. (Employer, 2011)*
- *Partnerships with the schools work by reaching out both ways…We provide internships…. We take on…roles in terms of advisory and curriculum. This way we know the program. It's nothing dramatic, they call when they need a spot and we try to fit it in. (Employer, 2011)*

In this case study, the Massachusetts Life Science Education Consortium (MLSEC) is the most prominent example of an effort to improve workforce coordination and labor market planning broadly across the state. Employer engagement is critical to the success of such an effort. To date, several employers have consistently engaged in MLSEC; however efforts to increase employer engagement are underway (Hartford, 2010). One employer representative viewed participation much in the same way as those describing their involvement in Job Shadow days; meaning the employer does not directly benefit from participation, but is fulfilling social responsibility objectives for the firm. Another employer argued that industry involvement is not just about social responsibility. Employers have a responsibility to participate in the educational system. In other words, employers and industry experts that hire and train workers should be an integral part of the education system; however, coordination efforts pose challenges with respect to aligning efforts across institutions (or silos) (Employer Interviews, 2011).

Case summary

The case study analysis finds that the core life sciences industries in Massachusetts have experienced consistent growth during the past decade and that this growth has been primarily driven by research and development services. In comparing industry performance for 2000-05 and 2005-10, the analysis also finds that employment growth and industry concentration intensified during the second half of the decade. Further, it finds that the core life sciences have outperformed the remainder of the innovation economy during the decade.

Case study findings raise the concern that economic development efforts and the innovation economy are contributing to increased earnings inequality more broadly. Meaning that the innovation economy is providing benefits to the highest skilled and highest paid members of the workforce while leaving many others behind. In fact, development in the innovation sectors has contributed to higher earnings at the top of the income ladder and has made no difference in earnings for those at the bottom. The case study also notes that the innovation sectors alone do not explain increasing earnings inequality in Massachusetts; there are many forces in the state's economy contributing to this growing divide.

Expanding downstream operations in the Massachusetts life sciences has been a desirable goal for the state. The opportunity to increase manufacturing activity in the state is attractive to most stakeholders, namely because it would help rebuild a job base accessible to many residents possessing blue collar or technical skills and to other regions outside the metro core with less costly real estate. Massachusetts has seen some commercial growth related to manufacturing in these sectors, but there is no evidence that growth is concentrating in the state (relative to other states). Industry growth outside of the metropolitan core has been relatively minimal with the exception of the Worcester I-495 region. Although the Northeast region of Massachusetts has not expanded in terms of life sciences employment, that region of the state provides a substantial amount of life sciences employment opportunities. The case study analysis finds that mid-skilled or technical jobs in downstream operations have experienced limited growth, while management, business and professional STEM occupations have seen the greatest growth. Lastly, biotechnology and pharmaceutical firms are driving a large part of the growth in clinical trial activity and Massachusetts has been able to attract a portion of this. However, the proportion of clinical trial activity that the state is getting is declining relative to all clinical trial activity in the United States.

With respect to equitable outcomes, the case study finds that outside of the Boston-Cambridge core, the Worcester I-495 region has benefited from growth and concentration of life sciences industries. Other regions in the state have seen little or declining changes in employment. Growth for sub-state regions has been most prominent in the second half of the decade. The study also shows that mid-skilled workers and workers with a high school diploma have not benefited from industry growth. Further, both mid-skilled workers and workers with a bachelor's degree have been at least twice as likely to be employed in other high tech industries as in the life sciences. Finally, although women and minorities (particularly black or African American and Hispanic) are underrepresented in the innovation economy, they appear to have greater access to employment in the life sciences when compared to high tech industries.

CHAPTER 6

POLICY DISCUSSION AND CONCLUSION

The goal of this research is to understand whether economic development planning can simultaneously ensure efficient outcomes for industry while encouraging more equitable outcomes for different communities or groups of workers within the state. It uses a case study methodology to examine growth and change in the Massachusetts life sciences sector between 2000 and 2010. In addition to showing that the life sciences cluster has sustained competitive advantage in Massachusetts, the research pays particular attention to equity outcomes. The research finds that in the context of sustained competitive advantage, the life sciences industry has expanded outside of the Boston-Cambridge core to the Worcester I-495 region and has provided greater access to employment for women and minorities than other sectors in the innovation economy. At the same time, however, the benefits associated with growing the industry downstream have not been realized. Although manufacturing shipments have increased in the Massachusetts life sciences sector during the case study this has not coincided with an increase in production jobs for the sector. Further, there is a broader concern that increased growth in this industry has been accompanied by greater earnings inequality for the state. This case study is limited in that it is not possible to make a causal claim between the effects of economic development policies and industry performance and labor market outcomes. The timeline for the case study is limiting as well since we would expect the effects of the policies to carry out beyond 2010.

This case study defines efficiency as sustained competitive advantage achieved through continuous innovation and through the support of a number of public and private institutions resulting in job growth and the generation of new wealth. Ideally, state public policies should not interfere with innovative progress or job creation and should work to make the state attractive to new and expanding businesses. For the most part, this is what we have seen economic development policies and initiatives aim to do in the Massachusetts life sciences cluster. At the same time, at least between 2000 and 2010, income inequality in the state has grown at increasing rates. Despite industry growth and new wealth, shared economic prosperity has not been secured, inequality is not diminishing and economic conditions are not improving for everyone. Obviously the burden of inequality does not rest on the life sciences industries or the innovation economy alone. Yet, economic development and industry stakeholders could make greater contributions to equality of opportunity and equitable outcomes, including acknowledging equity goals in their agenda setting. These contributions need not sacrifice the state's leading competitive assets; for example, the state's academic anchors, its lead in venture capital funding, and its ability to capture strategic and productive activities within the global pharmaceutical and healthcare markets.

Is sustaining the state's competitive advantage in the life sciences really a tradeoff with equity? Or are there ways to strike a balance and encourage shared economic prosperity? Equity goals present in the current economic development agenda (e.g., advancing the role of community colleges and increasing manufacturing activity across the state) have not posed a tradeoff with sustained competitive advantage; more often they have been viewed as complimentary. Therefore, the extent that these goals have become a reality is the product of a social bargain amongst stakeholders – it has not been about a tradeoff. The Massachusetts Life Sciences Education Consortium's ability to advance the role of the community college system in the life sciences industries is an important example in the case study. The consistent, reputable leadership of a third party (MBEF) coupled with objectives that accommodated the needs of multiple stakeholders worked. Too often though, economic development agendas have relied on the actions and decisions of individual employers to lead efforts; therefore gains in equity have been ad hoc. Since no single firm determines whether the state sustains competitive advantage in the life sciences, broader industrial and economic outcomes should be used to guide decision makers. Voices from across institutions should be considered. Reframing the goal more broadly with respect to shared economic prosperity to include both the generation of new wealth and the decline of inequality encompasses a larger group of stakeholders; therefore requiring more sophisticated policy deliberation, not just the usual profit or cost motivated objections voiced by employers.

Sustaining competitive advantage and increasing wealth alone is not sufficient for a region that also cares about social inclusion. Shared economic prosperity must include a reduction (or at least not a worsening) in inequality. In part, this can be accomplished by improving equality of opportunity. Our existing institutions set a framework for doing this, but we need stronger standards and more innovative practices. Recent program developments under the STEM initiative and through our educational system that explicitly address advancement for women, minorities, unemployed blue collar workers and first-generation college students, are good examples. But these programs have not yet come to scale relative to the industry. Additionally, achieving equitable outcomes (e.g., a fair distribution of new jobs) requires non-market mechanisms. A region's residents and planners must decide how and to what extent economic gains will be distributed. Overall, this calls for a more active and assertive role for government to lead equity objectives in the sphere of economic development and for a greater expectation on employers operating in the state's economy to participate in planning.

A more active role for government with respect to equity

The government needs to be a leader with respect to setting and implementing equity goals within economic development policy. When making policy choices about economic development and the innovation economy, the discussion needs to include a broad group of stakeholders, not just industry and science. The region's workforce contributes to the fiscal health of the state and these revenues can be used to support the local service sector and workforce diversity initiatives.

Tax revenues

Khatiwada et al., (2007) found that the life sciences workforce makes higher mean net fiscal contributions when compared to all other workers in the state. Authors calculated the mean contribution of a life sciences worker to Social Security, retirement, state and federal taxes to be $21,019 per year. This is $9,700 more per year than the average worker in all industries for the state. For state income taxes only, the average life sciences worker pays $3,334 per year compared to the average of $1,992. This is a difference of $1,342. We can use this average to estimate the additional fiscal impact of the life sciences workforce for a year to the state. In 2010, the life sciences workforce was more than 90,000. This equals more than $125,000,000 in additional revenue per year for the state. This additional contribution made by the life sciences workforce is already more than enough to cover the 10-year, $1 billion Life Sciences Act and could be used specifically to fund programs and initiatives that address equity goals. Some ideas are addressed below.

Local services sector

Economic development in the innovation economy can include parallel initiatives so that investments in the life sciences and other high technology are accompanied by improved standards in the local services sector. Many scholars (e.g., Bartik, 2003) continue to advocate for federal intervention in the low-wage labor market. Stronger national policies that address poverty and work are viewed as essential in diminishing inequality in our economy. However, other authors (Clark & Christopherson, 2009; Donegan & Lowe, 2008; Osterman & Shulman, 2011) argue that more can be done at the state or local level. For example, Osterman and Shulman (2011) provide a recent review of local and state initiatives that are aimed at improving standards in the labor market – particularly the low-wage labor market that encompasses many local services. These authors argue that education and training initiatives are only part of the solution and employment standards must be addressed through formal policies and better practices to improve job quality. Job quality includes both wages and working conditions. Jobs in the local services sector support professionals in other sectors, including the life sciences.

Retail, food services, and accommodation industries (to name a few) provide needed services for other workers who need, for example, their clothes cleaned or to eat lunch during the workday. Political leadership can have sway over job conditions in the local services sector, but making real change takes time, especially meaningful changes that both support improving wages and working conditions and simultaneously providing needed services to working professionals. The local services sector needs to become a priority when thinking about shared prosperity.

Recent federal increases in the minimum wage have been followed by state and city level increases above the mandated threshold. Washington State has the highest state minimum wage of $9.19. The City of San Francisco has a minimum wage of $10.74. Recently, the city of San Jose (the heart of Silicon Valley) voted by ballot referendum to raise the city's minimum wage to $10 an hour and Seattle voted to raise their city's minimum wage to $15 an hour. These are cities that have benefited greatly from the innovation economy as has Boston and Cambridge. Similar legislation has been proposed in Massachusetts although it has not been enacted.

Economic development can also recognize and support union organizing in the local services sector. Massachusetts has a strong union base (compared to many other states) and a number of labor unions experienced in organizing and bargaining in the services sectors. For example, SEIU Local 615 has been raising awareness in the biotechnology industry about employment standards for building services workers, including rallying at the BIO International Convention in June 2012. Workers reason that biotechnology has received significant public investment and has thrived in Massachusetts. Therefore, the industry has a responsibility to help improve conditions across the labor market, not just at the top (Service Employees International Union, 2012).

Workforce diversity

Stakeholders are interested in workforce diversity issues and improving access to the industry for a wider (and deeper) pool of workers. Improving equality of opportunity will enhance the region's competitive position, however it is not a costless endeavor and it is not clear that our existing institutions are structured well for doing this, at least not to the scale of the industry. In Massachusetts there are good program models and practices to build on. For example, in this past year Worcester Polytechnic University has developed a STEM engagement program for middle school girls. This has included hosting a Girl Scout event called "Geek is Glam" where girls learn about STEM innovations and talk with women who work in these fields. Advancing Women in the Business of Science and Technology (WEST) is a women's forum launched in 2000. WEST is now a developed network for women with advanced degrees who are interested in working for industry. There are also a few examples of programs that have focused explicitly on minority students. Most recently, there are initiatives tied to the community college system and, although they are not exclusively minority, are believed to help advance minority students through the community college system to graduation or transfer to a 4 year institution.[11] The Massachusetts Transformation Agenda, which

[11] For examples, see The Massachusetts Transformation Agenda at http://www.masscc.org/partnerships-initiatives/redesigning-community-college-education-and-training and a report from Jobs For the Future (2013) "Advancing Underrepresented Minorities in STEM Education and Careers" at http://www.jff.org/sites/default/files/u3/JFF-ATD-NACME_101513.pdf.

envelopes these community college initiatives, is also expected to improve job market prospects for the unemployed and first-generation college students.

In addition to women and minorities, we need better ways to measure the impact of hiring on local unemployment, first generation college graduates, the state's veterans, and young adults. The Internship Challenge run through the MLSC could alter some of their criteria. Instead of having a primary focus on the type of firm (esp. small firms), criteria could be focused on types of workers. Not including large employers in the Internship Challenge has meant cutting out participants' access to a large swath of jobs and career paths. Wage subsidies could be attached to STEM programs that address diversity issues, as well as the public education system which graduates mostly state residents. Further, infrastructure projects and tax credits funded through the MLSC could operate on a community benefit agreement model. This would mean setting hiring standards and diversity goals based on the immediate community and could include ongoing operations, not just the construction and expansion phases of a project.

A more responsible role for employers

Employers make choices. There is not just one way to do things and it is possible to develop new best practices and set better standards. Employers need to participate in economic development in general, not just when they have specific, immediate unmet needs. Economic development agendas should put more responsibility on employers to participate in initiatives that engage the education and training system, improve standards in the hiring process and contribute to occupational development.

Engaging with public education

Workforce training poses a conundrum in this sector. Despite the fact that life sciences employers need a well trained workforce; employers can be reluctant investors in the training and education system. Ultimately those training investments will be held by the worker and are portable. Well-trained workers from one firm can move on to another. However, training and education programs know that to deliver a quality program they must engage employers in the process. These efforts usually result in engaging a few firms with medium term skill needs that match the program. It may not be practical to require education and training programs to be highly flexible and adaptable to the immediate needs of employers. These programs often have longer time horizons when compared to the immediate hiring needs of employers. Traditionally training and education programs are not that fungible, nor should they be because of the long time horizon needed to develop human capital for future economic development. To address the immediate needs of employers there need to be special types of training and education programs for specific employers (e.g. corporate education and extension programs). These are good, but these programs benefit incumbent workers and individual firms, they are not producing broad benefits for the regional economy.

Alternatively, what would happen if all firms were required to be at the training table – or at least all firms that benefit from the public economic development incentives to have to be at the training table? Can the industry find a way to collectively invest in the public university and college system or collectively utilize public training subsidies with the goal of benefiting the competitive regional environment? Designing career pathways for the state's residents, developing thoughtful diversity initiatives, and identifying best practices related to job structures could go a long way if accomplished collaboratively.

Economic development agendas should require life sciences employers to invest resources and be accountable to the system and participate in labor market planning. Employers are but one stakeholder in the system of education and training and they have a responsibility to invest in and support the system. Particularly in a field like the life sciences where entry-level workers need general skills training, those skills are transferable across firms and all employers are relying on the educational system to provide them. Asking employers to voluntarily engage in the education and training planning only when it meets a specific or immediate skill need is insufficient (and likely inefficient).

For example, stakeholders can work together to advance the agenda for the Biomanufacturing Roundtable to address workforce and training issues. The Biomanufacturing Roundtable has been successful at pulling together business leaders in the sector from across the state to work on business environment issues, particularly state and national tax structures (Reynolds, 2009). It would be good to expand the agenda of this group to look at workforce issues and sub-state regional issues. The group is well situated to engage in labor market planning and address specific issues for different regions across the state. The Roundtable could work together with public higher education as well as the MassBio Education Foundation in a similar structure to what MBEF has already set up. Further, more consideration could be given to expansion across the state and the opportunities and challenges faced by different regions in the state. For example, the Roundtable could identify the impediments to attracting new and additional manufacturing in parts of the state that have seen less growth or decline like Western Mass and the South Shore.

Additionally, workforce development stakeholders have been skeptical about the claim that technical jobs have high demand for mid-skilled workers. Case study findings support this skepticism. There is no evidence presented here that suggests mid-level workers have been in high demand or growing demand in the innovation economy during the 2000 to 2010 period. However, the efforts of employers to work with community colleges and extension programs and the work of the MLSEC suggests differently. More realistic labor market planning and making employers accountable for their investments in the training and education system would provide a better understanding of what community colleges can do and ultimately can be conducted in conjunction with diversity efforts.

Recruitment and hiring

Becoming more transparent about hiring and recruitment strategies is a good thing. This does not cause good employers to lose their edge. Third party intermediation, for example, staffing services and Monster.com, does not ensure equality of opportunity by itself. These services may help make efficient hiring decisions, but need to be more closely examined in terms of who is being screened out and why (see Davidson, 2013 for example). Intermediaries must be part of any employer engagement strategy. Employers can require their staffing services to engage in economic and workforce development initiatives. Staffing services often have a wealth of information about what skills employers are looking for. Large staffing companies will benefit from networking by being involved in economic development initiatives and workforce strategies like those at MBEF. This may mean encouraging a longer term view among staffing services or compelling them to participate as part of contract with their customer.

Small employers who use Monster.com could give more thought to how they use these tools. Because they operate in smaller workplaces, they have more immediate information on job needs that allows them to plan ahead; in small workplaces this information is more apparent. A larger pool of small employers participating in labor market planning could be hugely beneficial to both them and the workforce. They would learn from each other on workforce strategies and as a group they have a significant number of jobs.

Occupational development

Employers structure job opportunities, job access, and job outcomes (e.g. wages) based on operational and competitive concerns, while relying heavily on a region's educational and training system. They are the ones primarily in charge of occupational development, especially in the absence of unions and professional associations. Therefore, they have a responsibility to create linkages across the training and education system and the industry. In order to deepen the impact of economic development strategies, other actors know that employer engagement is critical. In this context, other actors can learn about the kinds of work systems and skill requirements in place inside companies and help identify common needs across groups of firms. Only once employers are engaged in this manner, can economic and workforce development effectively devise strategies and subsidize training. Through this type of collaboration, economic development actors can begin to offer insights that illustrate the value of equity goals and the manner in which equity goals align with efficiencies.

For example, the MBEF has taken an important leadership position in this area with its new community college rating system, which has resulted from collaboration with numerous stakeholders both in the field of education and firms within the industry. In a manner of speaking, the Massachusetts Life Sciences Education Consortium with MBEF at the helm has taken on the role of a professional association for technicians trained in life sciences laboratory and manufacturing environments. In addition to helping set standards in curriculum and programs and engage industry in the educational process, this consortium benefits students and workers in the fields of biotechnology manufacturing and laboratory technicians. Students and workers benefit from increased transparency in the school to career trajectory. They also benefit when graduating from a program that has approved standards that industry agrees with. MBEF helps form a focus point for which students and graduates can be in the spotlight. The consortium also has the potential to improve labor market planning, which increases job security for program graduates.

Conclusion

The state of Massachusetts is a leader in the life sciences. This leadership position has been secure as the industry sector continues to grow and innovate. Given this, it is now time to focus more clearly on how growth in the life sciences can contribute to shared economic prosperity. Equity does not need to come at the price of efficiency.

Instead, the government can ensure a broader debate and enable stronger social bargains. Likewise, employers alone do not lead this effort, but have a responsibility to engage in development efforts and planning initiatives.

APPENDIX A

DESCRIPTIONS OF SELECTED ECONOMIC DEVELOPMENT POLICIES AND INITIATIVES IN THE MASSACHUSETTS LIFE SCIENCES INDUSTRIES

Exhibit 1 *MLSC Infrastructure Investments*

The Massachusetts Life Sciences Act of 2008 designated a number of capital investments to be stewarded by the Massachusetts Life Sciences Center (MLSC). These capital investments were targeted at infrastructure projects believed to stimulate long term job growth and expand the number of areas in the state that were “life sciences ready”. These projects include:

- *Albert Sherman Center at UMass Medical School:* The Sherman Center is a research and education facility, housing a number of research outfits (including bioinformatics) and provides space for 100 individual investigators. The completed project should generate 730 new life sciences jobs in central Massachusetts.
- *Worcester Polytechnic Institute/Gateway Park:* The Gateway Park in Worcester expands Worcester Polytechnic Institute’s biomanufacturing facility for training. The park also includes an existing location for Massachusetts Biotechnology Initiative (business incubator space) which has graduated 30 companies since 2000, and has about 40,000 sq. ft. in lab and office space.
- *Framingham Wastewater and Pumping Station:* This is an infrastructure project at Framingham Technology Park to improve the waste water system and assist Genzyme in completing their expansion in this area. This project is expected to encourage other companies to locate in the area.
- *MBL in Woods Hole:* Investment in Woods Hole leveraged private and public financing to renovate the Marine Biological Laboratory and build a training program on stem cell and regeneration for new scientists.
- *Tufts/Cummings School of Veterinary Medicine, NE Regional Biosafety Lab:* Investment in Grafton helped complete the New England Regional Biosafety Laboratory for Tufts University.
- *UMass Boston/Dana Farber Center for Personalized Cancer Therapy:* This infrastructure project supports joint research and training with the University of Massachusetts Boston and Dana Farber in building the Center for Personalized Cancer Therapy.

These investments have totaled $131 million and are projected to create more than 1,000 permanent jobs in the life sciences. Going forward, MLSC has instituted a competitive process for identifying new infrastructure projects for the state.

(Sources: Massachusetts Life Sciences Center, 2009, 2010, 2011)

Exhibit 2 <u>*MLSC Tax Credits*</u>

In 2008, the Massachusetts Life Sciences Center (MLSC) established a tax incentive program for life sciences companies who were committed to creating new jobs in Massachusetts. Eligible companies must be a registered life sciences firm with MLSC and demonstrate a viable expansion plan. There is a variety of tax credit options designed to support the higher cost processes associated with moving a product to market. Companies who receive the tax incentive commit to creating a specified number of jobs and consent to being audited on an annual basis to ensure that the new jobs created remain over a five year period. Tax incentives have been awarded for 2009 and 2010 and the companies who have received tax incentives for 2009 have submitted their first annual progress report. In 2009, the MLSC awarded $24.5 million in tax credits to 28 companies which in total committed to creating 918 jobs during the year. The first round of annual progress reports resulted in some "claw backs" as a handful of companies failed to meet their commitments. In total for 2009, MLSC provided $17 million in tax credits in return for 607 new jobs. In 2010, a new round of tax incentives worth $23.9 million has been awarded to 30 companies for nearly 1,000 new jobs. By the end of fiscal year 2011, $45 million had been committed in tax credits with life sciences companies committed to creating at least 1,600 new life sciences jobs. This translates into costing the state just under $27,000 per new life sciences job.

(Sources: Massachusetts Life Sciences Center, 2008, 2009, 2010, 2011; State House News Service, 2010)

Exhibit 3 <u>*MLSC Internship Challenge*</u>

The Internship Challenge is funded through state appropriations each year and hosted by the Massachusetts Life Sciences Center (MLSC). This internship program has run each summer since 2009. In its first year, the Internship Challenge attracted over 500 applicants, where 100 interns were placed in 59 companies. Students eligible to apply include those working towards master's and undergraduate degrees (either 4-year or 2-year), occupational certificates and vocational training. The MLSC conducts outreach to schools and employers, promotes the program, hosts the web interface where students upload resumes and employers search and review candidates, and provides assistance to users as needed. MLSC pays qualifying employers up to $15 an hour for a 12 week internship. The maximum cost per intern is $7,200.

A major programmatic change to the Internship Challenge starting in 2010 was that it limited eligibility for wage subsidies to employers with 100 or fewer employees. MLSC reported that smaller employers gained greater value from the paid internship experience, whereas larger companies usually had an affordable internship program in place. Additionally, the Internship Challenge grew in its second year in respect to all aspects. In 2010, there were 899 applicants, of which 170 interns were placed with 94 employers. The length of the internship was increased from 8 to 12 weeks and the investment from the Center increased from $500,000 to $1,160,000. Forty-seven educational institutions were represented by student interns, six of which were community colleges. Students representing community colleges increased from 2 in 2009 to 13 in 2010.[12] In 2010, the MLSC conducted a survey of its 2009 intern cohort. The Center found that one year later, 21% of the interns had moved into graduate STEM programs, 19% were employed at the company where they interned and 29% were employed in the sector, but not with the interning company.

(Sources: Massachusetts Life Sciences Center, 2008, 2009, 2010, 2011; Windham-Bannister & Mudawar, 2010)

Exhibit 4 *MLSC Equipment and Supplies Grant Program*

Most recently, the Massachusetts Life Sciences Center (MLSC) launched an equipment and supplies matching grant program in October 2010. Eligible grant recipients are vocational schools, community colleges and other 2-year degree and certificate programs, workforce development and labor organizations. Maximum grant awards are $250,000 per institution and grants greater than $100,000 must have an industry match. In its first year, the grant program awarded $3.4 million to 32 institutions in the state. Nine community colleges received awards, four of which included an industry match from biotechnology companies. Awards were also given to Boston University and Worcester Polytechnic Institute for non-degree certificate programs. The Massachusetts Biotechnology Education Foundation also received an award and a matching grant from the state's trade association, MassBio. The majority of the remaining awards went to vocational/technical high schools.

(Sources: Connolly, 2010; Massachusetts Life Sciences Center, 2011)

Exhibit 5 *MLSEC Community College Endorsements*

The Massachusetts Life Science Education Consortium (MLSEC) is an initiative led by the MBEF starting in 2009. Following the completion of the Life Sciences Talent Initiative in 2008, MassBio's Education Foundation (MBEF) and other stakeholders strategized on ways to better connect industry with the state's college and university biotechnology educational programs. The LSTI report had indicated that there was a disconnect between the higher education system and industry. Evidence collected from focus groups and surveys suggested that employers did not understand what the system of higher education was turning out. Further, a survey of education and training programs showed that biotechnology and other industry relevant programs were many and varied.

The Massachusetts Life Science Education Consortium (MLSEC) was formed in 2009 under MBEF's leadership to help create linkages between the higher education system and industry employers. The consortium is composed of college and university presidents and some industry leaders. MBEF is responsible for facilitating the consortium and

[12] The MLSC annual report for 2011 shows that community college involvement did not grow in the third year, despite the overall program growing and having positive outcomes for more highly educated students.

providing administrative oversight, staff support and organizational resources. External funding for the consortium has been limited until recently.

The first area of focus for the consortium has been to develop standards and core competencies for community college curriculums which are industry endorsed. In December 2010, eight community colleges received industry endorsements for their biotechnology related education and training programs. Silver endorsements were provided to programs that offered curriculums that addressed a set of required competencies. Gold endorsements were provided to programs that met the competencies but also provided an internship as part of the program.

(Sources: Hartford, 2010; Massachusetts Biotechnology Education Foundation, 2009; Procknal, 2010)

Exhibit 6 *MassBio BioReady™ Communities Campaign*

Since 2008, MassBio has assisted municipalities in assessing communities as location sites for biotechnology companies. To date, there are more than 60 communities in Massachusetts that have a BioReady™ rating. MassBio provides informational seminars which describe the types of facilities that biotechnology companies need and the regulatory issues related to locating a biotechnology facility. MassBio works with city officials to develop a rating for the community. Biotechnology facilities are very similar to other industrial facilities, but do have distinct requirements with respect to exhaust systems and climate control. Progressive ratings provided through BioReady™ are bronze, silver, gold and platinum. A platinum rated community meets several layers of requirements. These include having:

- Water and sewer capacity for industrial areas
- An official point of contact for the biotechnology business community
- Mechanisms to help speed regulatory and development processes
- Participates in state-wide economic development initiatives
- Pre-permitted sites for biotech or existing biotech industry activity, including buildings or shovel ready land with at least 20,000 sq. ft. of capacity
- Adopted NIH rDNA guidelines

(Sources: Abair, 2011; Massachusetts Biotechnology Council, 2012)

Exhibit 7 *Biomanufactuing Roundtable*

Research by Reynolds (2009) found that for companies locating their first clinical manufacturing site, 60 percent located within 100 miles of their research and development facility. And about 40 percent of companies located their first commercial manufacturing facility within 100 miles of their research operations. Subsequently, these percentages decline as a company expands to additional facilities. Industry research developed by the Collaborative found that executives were resistant to locating downstream activities in Massachusetts, not because of labor costs, but because of permitting and regulatory issues. Although MassDevelopment and MassBio (among others) have initiatives in place to help with locating and attracting business in the life sciences, there had been little economic development activity focused specifically on manufacturing.

Massachusetts holds a competitive advantage in biomanufacturing because of its cluster assets, talent and innovation capacity, and strong research and development sector. However, impediments to industry growth have been federal tax policy, underdeveloped infrastructure, the cost of living, and a number of workforce issues. The ground work for the Roundtable has been set and additional outcomes from this work may become apparent in the future. Most recently, the Biomanufacturing Roundtable has been moved out of the Collaborative and now resides under the MLSC.

(Sources: Massachusetts Life Sciences Center, 2011; Massachusetts Life Sciences Collaborative, 2012; Reynolds, 2009)

APPENDIX B

LIST OF NAICS CODES

Table 19: Core Life Sciences Industries

NAICS Codes	Industry Name
3254	Pharmaceutical and medicine manufacturing
334510	Electromedical apparatus manufacturing
334517	Irradiation apparatus manufacturing
3391	Medical equipment and supplies manufacturing
5417	Scientific research and development services

Table 20: Supporting Life Sciences Industries

NAICS Codes	Industry Name
	Industry Name
325188	All other basic inorganic chemical mfg.
325199	All other basic organic chemical mfg.
333314	Optical instrument and lens manufacturing
423450	Medical equipment merchant wholesalers
423460	Ophthalmic goods merchant wholesalers
42421	Druggists' goods merchant wholesalers
44611	Pharmacies and drug stores
44613	Optical goods stores
524114	Direct health and medical insurance carriers
541380	Testing laboratories
621	Ambulatory health care services
622	Hospitals
6231	Nursing care facilities, skilled nursing

Table 21: Other High Tech Industries

NAICS Codes	Industry Name
3341	Computer and peripheral equipment mfg.
3342	Communications equipment manufacturing
3344	Semiconductor and electronic component mfg.
3345	Electronic instrument manufacturing (w/o LSCore)
3364	Aerospace product and parts manufacturing
5112	Software publishers
5161	Internet publishing and broadcasting
5179	Other telecommunications
5181	ISPs and web search portals
5182	Data processing, hosting and related services
5415	Computer systems design and related services
5413	Architectural and engineering services (w/o Testing Labs)

Table 22: Census PUMA codes by sub-state region in Massachusetts

Sub-state region	Corresponding PUMA codes
Boston-Cambridge Core	2900; 3000; 3100; 3200; 3300
Suburbs/128	2600; 2700; 2800; 3400; 3500; 3700; 3800
Northeast	500; 600; 700; 800; 900; 1000; 1100; 1200; 1300
South Shore, Cape and Islands	3900; 4000; 4100; 4200; 4300; 4400; 4500; 4600; 4700; 4800
Worcester/I-495	300; 400; 1400; 1500; 2100; 2200; 2300; 2400; 2500; 3600
The West	100; 200; 1600; 1700; 1800; 1900; 2000

APPENDIX C

INTERVIEW PROTOCOLS

Topic areas for in-depth interviews with targeted stakeholders.

- Recent economic development successes and current priorities supported by MassBio
- Recent political/economic changes or industry trends (e.g. economic recession, policy initiatives, business strategies) which may impact job growth for Massachusetts or for the biotechnology sector in general
- Perspective on the labor market needs of employers who are locating or expanding their operations in the state
- With respect to the LSTI report, thoughts regarding the recommendation that the Commonwealth should strive to improve coordination and communication between industry and higher education
- Descriptions of targeted programs designed to address labor market/workforce needs in the region.
- Overview of other stakeholder initiatives

Main protocol for focused interviews with HR/operations executives/CEOs

- Approximately, what percentage of your workforce holds a bachelor’s degree or less? And what kinds of jobs do those employees fill?
- What kinds of strategies does the company use to recruit and hire these workers?
- What are the advancement prospects for this portion of your workforce?
    - Internally (e.g. promotion, skill upgrading, increased responsibilities)
    - Externally (e.g. when employees leave your company, what do you know about where they go?)
- How have you benefited from engaging [particular policy initiatives]?

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