Engines of Economic Growth

The Economic Impact of Boston's Eight Research Universities on the Metropolitan Boston Area

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Executive Summary

After nearly a decade of robust economic growth, the Boston metropolitan area began in 2001 to feel the effects of the national recession. While the recession may be relatively mild by historic standards, by the end of 2002 a real recovery had not yet materialized. A return to the vibrant growth that characterized the Boston area economy in the late 1990's thus cannot be taken for granted. Those with a stake in the region's economic future need to identify clearly the Boston area's strengths, and consider carefully how the region can most effectively build on those strengths.

Among these strengths is one that no other region in the U.S. can match. The Boston area is home to eight research universities[1]: Boston College, Boston University, Brandeis University, Harvard University, the Massachusetts Institute of Technology, Northeastern University, Tufts University and the University of Massachusetts Boston. Just as they helped the Boston metropolitan area recover from a severe regional recession in the 1990's, these eight universities are today providing a foundation for renewed economic growth in the years ahead.

The research universities are already well-positioned to play a central role in renewing the region's economy. They are among the region's leading employers, and one of its most reliable sources of job growth. Each year they turn out more than 30,000 graduates, providing to the region's leading industries a steady stream of highly-talented, well-educated workers. Their research programs are creating the new knowledge that will help ensure the Boston area's continued leadership in emerging areas such as genomics, proteomics and nanotechnology. And they are a seedbed for creation and growth of the dynamic young companies that over the next decade will drive the growth of the region's economy.

A few statistics help tell the story.

- The eight universities spent more than $1.5 billion on research in 2000. Research conducted at affiliated hospitals and institutes pushed the total over $2.5 billion. About 97 percent of this research was funded from federal and other non-local sources.
- In fiscal year 2000, the eight universities spent approximately $1.3 billion on purchases of goods and services from Boston area vendors.
- During the next four years, construction spending at the eight universities is expected to average as much as $850 million annually.
- In October 2002 the eight universities employed approximately 50,750 people — roughly equal to the total number of people employed in Massachusetts by Fidelity, State Street, FleetBoston, Raytheon and Gillette combined.
- Because they are less susceptible than many other leading industries to cyclical swings in the economy, the research universities are an important source of stability in the regional economy. Since October 2000, while the overall regional economy slid into recession, total employment at the eight universities grew by 2,000 jobs — an increase of 4 percent.

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[1] Defined here as institutions located within Route 495 that grant doctoral degrees, and that spend at least $10 million annually on research.

- The universities' spending on payroll and on purchases of goods and services within the region supported more than 37,000 full-time equivalent jobs in industries throughout the region in 2002, paying approximately $1.6 billion in wages.
- The universities were granted 264 patents in 2000, signed 250 commercial licensing agreements, and helped form 41 start-up companies.
- The concentration of major research centers in the Boston area — unmatched in any other U.S. region — is a magnet for investment by major U.S. and foreign corporations in new research facilities. Companies that have recently located or are now developing major research operations in the Boston area include Amgen, Merck, Novartis, Pfizer, Cisco and Sun Microsystems.
- Of the fifty early-stage start-up companies in the Boston area that attracted the most outside investment in 2001-02, 25 — including 7 of the top 10 — had connections to one or more of the universities. That is, they were engaged in the commercialization of technology first developed at one of the universities, were founded by a faculty member or graduate, started life in a university incubator, or had a CEO who had graduated from one of the eight.
- Approximately 310,000 of the eight universities' alumni live in the Boston area. They account for about 30 percent of all residents of the region who have four-year college or higher degrees.

This report, commissioned by the eight universities, documents their role in the growth and continued vitality of the Boston area economy. It also highlights challenges that the eight and the broader regional community must address, if they are to realize fully the universities' potential contribution to the region's future economic growth. Most important, the report demonstrates that if the universities are to play their increasingly central role in attracting, retaining and developing talent, creating new knowledge and developing new businesses and jobs, they must be able to develop, change and grow.

If the research universities are to remain competitive in student enrollment, scholarship and scientific research and development — if they are to remain eight engines of economic growth for the region — they must forge with state and local leaders and with their home communities a new recognition that their continued growth and vitality is inseparable from that of the greater Boston metropolitan area.

The next few pages summarize the report's major findings.

Developing the Region's Human Capital

- In 2000, 118,000 students were enrolled in undergraduate, graduate or professional degree programs at the eight universities. Together, the eight universities granted nearly 32,000 degrees, thus making available to the region's employers a steady stream of well-educated, highly-skilled workers.
- Approximately 310,000 graduates of the eight universities live in the Boston metropolitan area; together they account for approximately 30 percent of all residents of the region who have four-year or higher degrees.

- In an era in which the pace of economic change increasingly demands that workers become "lifelong learners," the research universities have emerged as major providers of continuing education. In the fall of 2000, the eight universities enrolled more than 25,000 people in non-degree programs.

The Role of University Research

- In 2000, research spending at the eight universities totaled $1.5 billion. Together they accounted for more than 95 percent of all college and university research spending in the area. When research conducted at the eight universities' affiliated hospitals and institutes is included, research spending totaled more than $2.5 billion.
- Funding sources outside the Boston area — federal agencies, foundations and corporations — accounted for 97 percent of all research spending at the eight universities.
- The universities contribute to the continued development of the region's economy through a wide range of research partnerships with regional companies both large and small. Examples include Northeastern's Barnett Institute (in biotechnology), Boston University's Photonics Center, MIT's Auto-ID Center, Harvard's Institute for Chemistry and Cell Biology and the Tufts School of Veterinary Medicine's partnerships with several Massachusetts corporations.
- The breadth of research strengths found among the eight universities creates numerous opportunities for collaboration. Sometimes collaboration occurs within institutions — for example, at Brandeis University's Rosenstiel Center for Basic Medical Research. Other collaborative efforts involve multiple institutions — for example, the Conte Center, a joint program of Harvard Medical School, Brandeis, Boston University, and Massachusetts General and McLean hospitals, dedicated to studying the neurological bases of schizophrenia. Similarly, UMass Boston's New England Regional Center for Ocean Science and Education Excellence is a collaborative effort that also includes the Woods Hole Oceanographic Institute, the New England Aquarium and the National Science Foundation.
- Some collaborations also link universities in the region to other research institutions throughout the region and the world. Northeastern's Center for Subsurface Sensing and Imaging Systems, for example, is a partnership with three universities and five research institutes stretching from California to Puerto Rico.
- The opportunity to participate in major research projects greatly enhances the education of both undergraduate and graduate students at the eight universities. Such participation turns university graduates into the most efficient of all instruments for transferring new knowledge and new technologies from the region's campuses to its employers.
- The concentration of major research centers in the Boston area — unmatched in any other U.S. region — is a magnet for investment by major U.S. and foreign corporations in new research facilities. Companies that have recently located or are now developing major research operations in the Boston area include Amgen, Merck, Novartis, Pfizer, Cisco and Sun Microsystems.

The Universities' Role in New Business Development

- Since the early 1980's, technologies first developed in university labs have become an increasingly important source for the development of new products and new businesses. In 2000, the eight universities:
  - Were awarded a total of 264 U.S. patents;
  - Entered into 280 agreements for commercial use of the results of university research; and
  - Assisted in the start-up of 41 new ventures created specifically to bring to market new technologies first developed at the universities.
- All of the universities have created "technology transfer" offices dedicated to promoting the translation of academic research into new products and businesses. In addition to negotiating agreements with companies that want to use the results of university research for commercial purposes, these offices provide extensive support to faculty members, students and others that want to start new businesses based on innovations developed in university labs.
- Research university faculty have been among the founders of leading Boston-area companies in a wide range of industries, including information technology, biotechnology, engineering, architecture and management consulting. Examples include Genome Therapeutics, Biogen, and Delphi Communications.
- The eight universities provide several types of support to faculty members and others in the university community who are interested in starting new businesses, including:
  - Seed money grants for further work on inventions with significant commercial potential;
  - Assistance in business planning;
  - Introductions to venture capitalists;
  - Assistance in recruiting a start-up team;
  - Incubator space.
- Research university graduates have also been a major source of entrepreneurial vitality in the Boston area. Ventures started by graduates of the eight universities during the past twenty years include notable regional companies such as Teradyne, EMC, Forrester Research, Staples, Mercury Computer Systems, Lycos, and Akamai Technologies.
- Several universities have organized formal programs aimed at educating student entrepreneurs, and helping them launch new businesses — MIT's "$50K," Northeastern's "$60K" and Tufts' Montle Prize business plan competitions, and Boston University's Bronner E-Business Center, for example.
- The eight universities are also the primary source of human capital for the region's venture capital industry; of 135 senior partners and other top executives at the 25 largest Boston-area venture capital firms, half are graduates of one or more of the universities.

- Several universities — most notably MIT, Boston University and Tufts — have been actively involved in the development of commercial research and office space, thus helping to accommodate the growth of companies generated (or attracted to the Boston area) by the universities.
- Of the fifty Boston-area start-ups that attracted the most early-stage investment in 2001-02, half — including 7 of the top 10 — had some relationship to one or more of the research universities.

The Research Universities as Employers

- In 2000, the research universities together employed 48,750 people (excluding students) — more than the number employed in the Boston area in banking, or in the manufacturing of computers and other electronic equipment — and had a combined payroll of approximately $2.5 billion.
- The universities offer their employees a wide range of opportunities to upgrade their skills, and thus improve their earning power.
- Because they are less susceptible than other leading industries to cyclical swings in the economy, the research universities are an important source of stability in the regional economy. Since October 2000, while the overall regional economy slid into recession, total employment at the eight universities grew by 2,000 jobs, to 50,750.

Purchasing and Construction

- In fiscal year 2000, the eight universities spent approximately $1.3 billion on purchases of goods and services from Boston area vendors.
- During the next four years, construction spending at the eight universities is expected to average as much as $850 million annually. University construction contributes to the continued growth of the regional economy in several ways:
  - Through the employment of local contractors and construction workers;
  - Through development of the facilities needed to support the continued growth of the universities' research and teaching activities; and
  - By creating an environment that will help universities attract (and help the region retain) talented students and scholars.
- The "multiplier effect" of the eight universities' spending within the region on payroll, purchasing and construction generated an additional $3.9 billion in regional economic output, $1.6 billion in wages and more than 37,000 full-time-equivalent jobs in 2000.

Student and Visitor Spending

- In 2000, spending by university students for housing, food, entertainment, transportation and other needs (excluding payments to the universities for tuition, fees, room, board, etc.) totaled an estimated $850 million.
- We estimate that local spending in 2000 by visitors to the universities — people attending major events such as commencement ceremonies, participants in conferences and continuing professional education programs, students' friends and families, etc. — totaled at least $250 million.

Helping Communities Meet the Demands of a Changing Economy

- While the continued growth of a knowledge-based economy has created many new opportunities for Boston area residents, it also poses several challenges for communities throughout the region.
- The eight universities are engaged in numerous efforts aimed at improving the quality of elementary and secondary education in communities throughout the Boston area. These include, for example, the Boston University/Chelsea Partnership, under which the University manages the city's public schools; UMass Boston's Pipeline program, which helps recruit, train and retain teachers in Boston, Cambridge and Somerville Schools; Boston College's THEMES program, which works with Boston teachers to more effectively integrate the use of technology into everyday classroom activities; and Northeastern's MathPower program, which is working to improve math instruction in Boston public schools.
- In addition to helping improve the quality of local schools, the eight universities provide a wide range of educational opportunities for individual elementary and secondary school students. These include, for example, Boston College's College Bound program, which helps students in Brighton and West Roxbury prepare for college, and Northeastern's Kellogg Partnership, which provides student teachers for after-school and Saturday programs in Roxbury.
- The universities also participate actively (and in many instances financially) in local community development efforts — from Boston University's involvement in the revitalization of Kenmore Square to Tufts University's support for the clean-up of the Mystic River watershed, with the goal of making the river "fishable and swimmable" by 2010.
- During the past several years, the research universities have become more and more active in helping communities address the problem of housing affordability, by:
  - Building residence halls and apartment buildings that can house thousands of students, thus reducing competition from students for a severely limited supply of moderately-priced housing. Between 1999 and 2004, the eight universities will have increased by approximately 6,400 the number of students housed in university residence halls and apartments.

– Participating directly in the financing and development of affordable housing for community residents — for example, through Harvard's "20/20/2000" program, which provides financing for non-profit housing developers, or through Northeastern's Davenport Commons project, which includes housing for both students and community residents.

Looking to the Future

During the next decade, the research universities could make an even greater contribution to the growth of the Boston area economy than they have in the past, for several reasons:

- The steadily growing importance of human capital in determining the economic health of cities and regions.
- The growing importance of scientific research and technological innovation as drivers of economic growth.
- The eight universities' strength in areas that are likely to be at the leading edge of economic growth during the years ahead, including information technology, genomics and proteomics, photonics and nanotechnology.
- Expected increases in federal research funding in several fields, such as biomedical research and research related to national security.
- The advantages that result, in an age of increasing scientific complexity, from having multiple research institutions with diverse strengths concentrated in one region.
- The universities' increasing effectiveness in translating the results of academic research into new products and new businesses.
- The universities' role, in an increasingly integrated global economy, in forging links between the Boston metropolitan area and other regions, institutions and businesses throughout the world.

There are, however, several challenges that the universities and the broader regional community will have to meet, if they are to realize fully the university's potential contribution to the growth of the Boston area economy. These challenges include:

- The need to maintain over the long term a strong federal commitment to basic and applied research, despite the fiscal pressures created by slower economic growth, increased defense spending and tax cuts.
- The need for additional space in which to accommodate the continued growth of the universities' research and teaching activities.
- The need to keep building on their support for entrepreneurial activity.
- The need to prepare all of the region's young people to take full advantage of the opportunities for learning that its colleges and universities offer.

Meeting these challenges successfully will require active collaboration among the universities, public officials and communities throughout the Boston area.

Introduction

After nearly a decade of vigorous economic growth, the Boston metropolitan area in 2001 began to feel the impact of a nationwide recession. Unemployment and vacancy rates rose, as many of the technology-based companies that had driven much of the region's recent growth fell upon hard times.

By late 2002, the recession seemed by some measures to have bottomed out, but the prospects for recovery remained uncertain. Both the recession and the seeming elusiveness of a sustained recovery offer a powerful reminder that even in a region that performed as well economically as the Boston area did in the century's last decade, prosperity cannot be taken for granted. To ensure that the Boston area participates fully in the coming recovery, community leaders, public officials and business decision-makers all need to identify and understand the competitive strengths on which the region can build, as well as the challenges and opportunities that lie ahead.

The Infrastructure of Innovation

Higher education has long been one of the Boston metropolitan area's largest industries, and eight research universities — Boston College, Boston University, Brandeis University, Harvard University, the Massachusetts Institute of Technology, Northeastern University, Tufts University and the University of Massachusetts Boston — have long constituted the core of that industry. The economic significance of the research universities, however, goes far beyond their role as a major industry in themselves. The services that the research universities provide are vital to the continued growth and development of a wide range of other industries — from information technology and biotechnology to finance to the arts — on which the region's economic future depends. They are, in effect, the intellectual infrastructure that supports the region's innovation-driven economy.

As the Boston area seeks to take advantage of the opportunities for growth that the next round of recovery will offer, it is essential that all of those with a stake in the region's future understand the role the research universities can play in building that future. Toward that end, the eight universities asked Appleseed — a consulting firm with extensive experience in analyzing the regional economic impact of colleges and universities — to undertake an assessment of their impact on the economy of the Boston metropolitan area.

Organization of the Report

This report presents Appleseed's findings.

- Part One of the report briefly describes the regional economic context within which the universities operate, and the scope and scale of their operations.
- Part Two examines the universities' contribution to the development of the region's human resources — the impact of university research on the regional economy — and the universities' role in the development of new businesses.
- Part Three of the report examines the research universities' significance as a major regional industry in themselves — as employers, buyers of goods and services, and sponsors of major construction projects. Part Three also highlights the impact of spending by students and visitors.
- Part Four discusses how the universities are helping the communities in which they are located respond to the demands of a changing economy — by helping to improve the effectiveness of local schools, and by supporting local community development efforts.
- Finally, Part Five of the report briefly discusses why the research universities' role in the growth of the Boston area economy could be even greater in the years ahead than it has been in the recent past — and the challenges that must be addressed if the universities are to realize their potential for contributing to the region's continued prosperity.

Acknowledgments

This report could not have been completed without the active support and cooperation of many people at the eight universities. Appleseed would especially like to thank Tom Keady, Jean McKeigue and John Havens of Boston College; Susan Paris, Kevin Carleton, Joe Grossi, Matt Burns and Richard Towle of Boston University; Andrew Hahn, James Hurley and John Hose of Brandeis University; Jane Corlette, Mary Power, Paige Lewin, Lauren Marshall and Brian Sinclair of Harvard University; Paul Parravano, David Cohen, Ken Campbell, Shelley Brown, Patti Richards, Steve Marsh, Jack Turner, Shawna Vogel, Kristen Collins and Cheryl Slowik of MIT; Jeff Doggett, Ronald Hedlund, Richard Porter and Jeanne Levesque of Northeastern; Barbara Rubel, Bill Edington, Nina Green, Cynthia Pollard, Dawn Terkla and Siobhan Houton of Tufts; Lisa Gonsalves, Winston Langley and John Ciccarelli of University of Massachusetts Boston; Clare Cotton and Alison Hitesman of the Association of Independent Colleges and Universities of Massachusetts; and Shayne Gilbert of Silverweave.

Part One:

The Universities in Context:

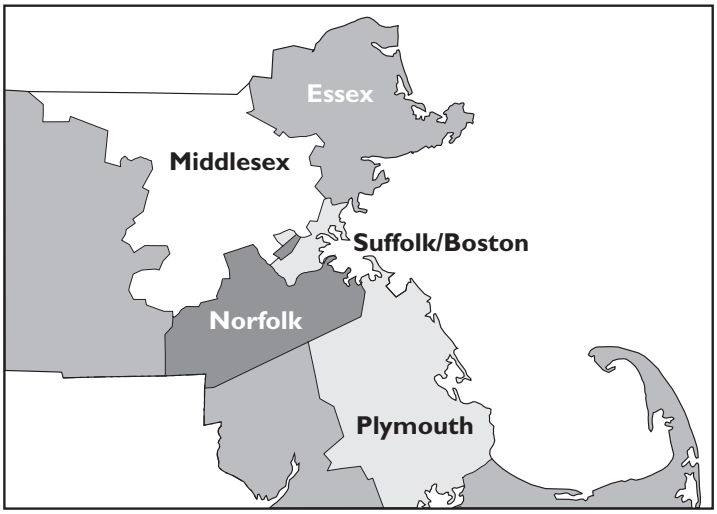
the Boston Area Economy

I. The Regional Economic Context

The Boston metropolitan area prospered in the 1990's. Following a major regional recession at the beginning of the decade, the metropolitan area — defined here as Suffolk, Norfolk, Middlesex, Essex and Plymouth counties — enjoyed an eight-year run of strong and sustained economic growth.

- Between 1992 and 2000, payroll employment in the Boston metropolitan area grew by 19.4 percent, to a total of 2.06 million jobs. Job growth in the region lagged only slightly behind the 21.4 percent increase in employment nationwide during the same period.[2]
- After adjusting for inflation, earnings per worker in the five-county Boston area grew at twice the national rate. Earnings per worker in the Boston area increased by 16.5 percent between 1992 and 1999, to $43,292. For the same period, earnings per worker at the national level grew by only 8.2 percent, to $32,711.[3]
- After several years of vigorous job growth, the overall unemployment rate for the five Boston-area counties fell in 2000 to 2.3 percent — well below the level most economists would define as full employment.[4]

Figure 1:
Boundaries of the Five Metropolitan Counties of the Boston Area



During 2001, however, as the national economy slipped into recession, the economy of the Boston metropolitan area began to falter as well. Many of the companies that profited so handsomely from the growth of the information and communications industries in the late 1990's were hurt badly by the collapse of the technology boom. By August 2001, employment growth in the Boston area had stopped, and the region's unemployment rate had once again risen to 3.4 percent.

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[2] U.S. Department of Labor, Bureau of Labor Statistics.

[3] U.S. Department of Commerce, Regional Economic Information Service.

[4] Bureau of Labor Statistics

The shock of the September 11, 2001 terrorist attacks on the World Trade Center and the Pentagon accelerated the downward slide. By January 2002, payroll employment in the Boston area had fallen by 2.3 percent — a loss of 47,000 jobs — and unemployment in the region had reached 4.3 percent. The office vacancy rate in the metropolitan area had reached 8.7 percent; and the vacancy rate for research space, 10 percent. A Milken Institute study of the impact of the terrorist attacks on the economy of U.S. cities estimated that in 2002 the ripple effect from the events of September 11 would cost the Boston metropolitan area more than 36,000 jobs.[5]

By late 2002, there were some indications at both the national and regional levels that the recession had bottomed out — although prospects for recovery remained uncertain. It cannot be taken for granted, however, that a national economic recovery will bring with it the vibrant growth that characterized the Boston area economy in the late 1990's. The Boston metropolitan regional community must focus once again on its core strengths, and ensure that it has in place the foundation that will be needed to take full advantage of the next economic upswing.

Sources of Regional Economic Growth

The Boston metropolitan area is one of the world's leading examples of a regional economy built on intellectual capital, defined by Thomas Stewart as:

> *Intellectual material — knowledge, information, intellectual property, experience — that can be used to create wealth.*

During the past few decades, the nature of competitive advantage has been changing, for both companies and communities. The importance of material assets has declined, while that of intellectual assets has increased.

> *Information and knowledge are the…competitive weapons of our time. Knowledge is more powerful than natural resources, big factories or fat bankrolls. In industry after industry, success comes to the companies that have the best information or wield it most effectively — not necessarily the companies with the most muscle.*[6]

A recent nationwide study of regional competitiveness led by Professor Michael Porter of Harvard Business School found that:

> *The most prosperous regions do not export natural resources or only physical products, but intellectual capital in various forms.*

Porter and his colleagues further note that advanced regional economies are marked by "specialization in a range of clusters," which they define as "geographically proximate groups of interconnected companies and associated institutions in a particular field, linked by customer, supplier or other relationships."

> *Clusters enhance competitiveness in three ways. First, they improve productivity, because firms have ready access to specialized suppliers, skills, information, training and*

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[5] Milken Institute, *Metropolitan Economies in the Wake of 9/11*, January 2002, p. 31

[6] Thomas Stewart, *Intellectual Capital: The New Wealth of Organizations* (New York: Doubleday, 1997), pp. ix-x.

> *technology in a demanding competitive environment….Second, clusters foster innovation by highlighting new needs and new processes, while giving companies the assistance and flexibility to try new things….Finally, clusters foster the creation of new firms through start-ups and spin-offs, and by attracting subsidiaries of firms based elsewhere. This reinforces cluster productivity and innovation. Establishing a business in a cluster is easier than elsewhere, because all the inputs are readily available.*[7]

In the Boston area, the fundamental importance of clusters built on intellectual capital is evident from the character of the region's leading industries. In 2001, the Greater Boston Chamber of Commerce published a report that identified five industry clusters as having driven the region's growth during the 1990's:

- ***High technology***, including computer hardware and software, telecommunications, instruments, and biotechnology;
- ***Financial services*****,** including banking, insurance, securities, investment management companies and venture capital firms;
- ***"Knowledge industries"***, including higher education and consulting and research firms;
- ***Health care*****,** including hospitals, nursing homes, clinics, practitioners offices and home care; and
- ***Visitor industries***, including hotels, restaurants, retailing, entertainment and the arts, and transportation and travel services.[8]

Between 1997 and 2000, employment in these five industry groups grew by 8.4 percent, to a total of 769,000. Other industries that serve as major suppliers to these five growth sectors — such as engineering, legal services, accounting and advertising — accounted for an additional 220,000 jobs in 2000.[9] Thus, the five major growth sectors and the industries that support them directly account for roughly 48 percent of all employment in the Boston metropolitan area.

In varying degrees, all of these leading industries are built on a strong base of human and intellectual capital. This may be self-evident in the case of technology-based industries such as software and biotechnology. But even Boston's tourist industry depends in part on the city's strengths in culture and the arts.

The Role of the Research Universities

The higher education sector — and more particularly, the eight research universities that are the focus of this study — plays a central role in the Boston area economy. As noted above, higher education is in itself the core of one of the region's leading industry clusters. In 2000, private colleges and universities in the region employed more than 65,000 people.

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[7] Professor Michael E. Porter et al, *Clusters of Innovation Initiative: San Diego* (Washington, DC: Council on Competitiveness, 2001), pp. 26-27.

[8] Greater Boston Chamber of Commerce, *Greater Boston's Leading Industries: Drivers of the Regional Economy,* pp. 6-15.

[9] Ibid., p. 3.

By several measures, higher education plays a greater role in the economy of the Boston area than in any other region in the United States. A survey of the ten largest U.S. metropolitan areas, conducted in 2000 for the Atlanta Regional Consortium for Higher Education, found that the Boston area ranked first in college and university enrollment per 100,000 population; first in degrees granted per 100,000 population; and first in per capita spending on higher education.[10]

The higher education sector, moreover, helps stabilize the regional economy. It is much less subject to cyclical swings in income and employment than are some of the region's other leading industries, such as financial services and information technology. In fact, because some people are more likely to remain in or return to school when the job market is soft, the overall impact of higher education on the regional economy may be mildly countercyclical.

The research universities are the largest enterprises in this sector. Together they employed 48,750 people in 2000 (excluding students), and had revenues totaling more than $5.8 billion.

Even more important than their role as a major industry in themselves, however, is the role that the research universities play in supporting the development of the region's other leading growth industries. ***The universities are, in effect, the intellectual infrastructure that supports the continued growth of the other leading clusters.***

The Massachusetts Technology Collaborative has suggested that the growth of what it calls the "innovation economy" depends on three factors — ***scientific research, technical skills and entrepreneurial initiative***.[11] The eight research universities are important sources for all three. They are the region's leading research centers, directly or indirectly accounting for billions of dollars in research spending each year. They annually grant tens of thousands of undergraduate, graduate and professional degrees in nearly every imaginable discipline. And they have supported the creation and growth of hundreds of new companies.

In a recent review of the increasingly complex linkages between universities and industry, Lewis Branscomb and Fumio Kodama have noted that "the economic sectors with the most rapid growth are those closest to the science base: microelectronics, software, biotechnology and new materials." These and other fast-growing sectors depend on a continuous flow of ideas and talent from universities.

Universities thus make significant contributions to economic growth, at both the national and regional levels. As Branscomb and Kodama emphasize, however, it is important to view these contributions not just as a series of individual transactions, or even as a series of relationships between individual universities and specific industries. Rather, they suggest that we view research universities as:

> *part of a network of people and institutions who possess high skills, imagination, the incentive to take risks, and the ability to form other networks to accomplish their*

[10] Atlanta Regional Consortium for Higher Education, *Higher Education in America's Metropolitan Areas: A Satistical Profile*, January 2001.

[11] Massachusetts Technology Collaborative, *Index of the Massachusetts Technology Collaborative 1999*, p. 6.

> *dreams…. The quality of social capital in a region will largely determine whether university-based entrepreneurial activity 'sticks' to the region's economy or slides away to more fertile ground.*[12]

This vision of research universities as an integral element in a broader "infrastructure of innovation" seems especially relevant to the Boston metropolitan area.

- Collectively, the eight universities make up a "community of knowledge" that help make the Boston area a more attractive place for leading scholars and scientists to live and work than any individual institution could on its own.
- Similarly, the concentration of so many universities in the Boston area helps to create an environment that attracts talented students to Boston from all over the U.S. and the world.
- Together, the universities offer Boston area residents a range of opportunities for learning — not just in their student years, but throughout their working lives — that few other regions can match.
- The proximity of the eight universities, and the variety of their strengths, encourages collaboration across institutional boundaries.
- The universities are closely connected to a web of other research institutions — hospitals where research and teaching take place, non-profit research institutes, government and corporate research centers and contract research enterprises. Together, they make the Boston area one of world's leading centers of research and development activity.
- The universities similarly have close ties to a network of private businesses that are also part of the region's infrastructure of innovation — venture capital firms, investment bankers, law firms and others. As participants in this network, universities play an active role in translating academic research and innovation into new businesses.

In all of these ways, the universities' collective impact on the region's economy is greater than the sum of their individual contributions. Together, they represent a source of economic vitality and competitive advantage that any other region in the U.S. (or the world) would envy. Moreover, they represent an asset that other regions could only replicate over a very long period of time — if at all. ***In an age when the lifespan of competitive advantage is increasingly measured in months rather than years, the research universities (and the other intellectual assets associated with them) represent one of the few enduring sources of regional competitive advantage.***

[12] Lewis Branscomb and Fumio Kodama, "University Research as an Engine for Growth: How Realistic Is the Vision?" Branscomb, Kodama and Richard Florida, eds., *Industrializing Knowledge: University-Industry Linkages in Japan and the United States* (Cambridge, MIT Press, 1999), pp. 8-9, 16-17.

II. The Boston Area Research Universities: Overview

This report focuses on the role of eight major research universities[13] in the economy of the Boston metropolitan area — and in particular, the ways in which they can contribute to the region's continued success in an economy built on intellectual capital. The eight institutions are:

Boston College

One of the nation's oldest and largest Jesuit Catholic universities, Boston College combines nationally-ranked undergraduate and professional schools, a growing scientific research enterprise, and a strong commitment to social justice. Its main campus is located in Chestnut Hill, on the Boston city line, and its Law School campus in Newton.

Boston University

BU is the largest of the eight universities in terms of total enrollment, and in the breadth of its programs is one of the most comprehensive. Its main campus is located on the south side of the Charles River; and its medical and dental schools are part of the Boston University Medical Center complex in the South End.

Brandeis University

The smallest of the eight in terms of enrollment, Brandeis, located in Waltham, nevertheless offers a wide range of undergraduate and graduate programs. Relative to its size, Brandeis is one of the nation's most research-intensive universities.

Harvard University

Harvard, the nation's oldest university, has its main campus in Cambridge, its health sciences campus in the Longwood area of Boston, and its business school in Boston's Allston neighborhood. It offers the largest and most diverse array of graduate and professional programs in the region.

Massachusetts Institute of Technology

MIT is one of the nation's leading universities focusing on engineering, science and management, and the region's largest academic research center. MIT is known not only for its scientific and technological research, but for its culture of entrepreneurship. MIT's main campus is located in Cambridge, and its Lincoln Laboratory — one of the nation's leading centers of national security research and development — is located in Lexington.

Northeastern University

Located in Boston's Fenway and Roxbury neighborhoods, Northeastern has the region's largest undergraduate enrollment. Northeastern characterizes its approach to education as

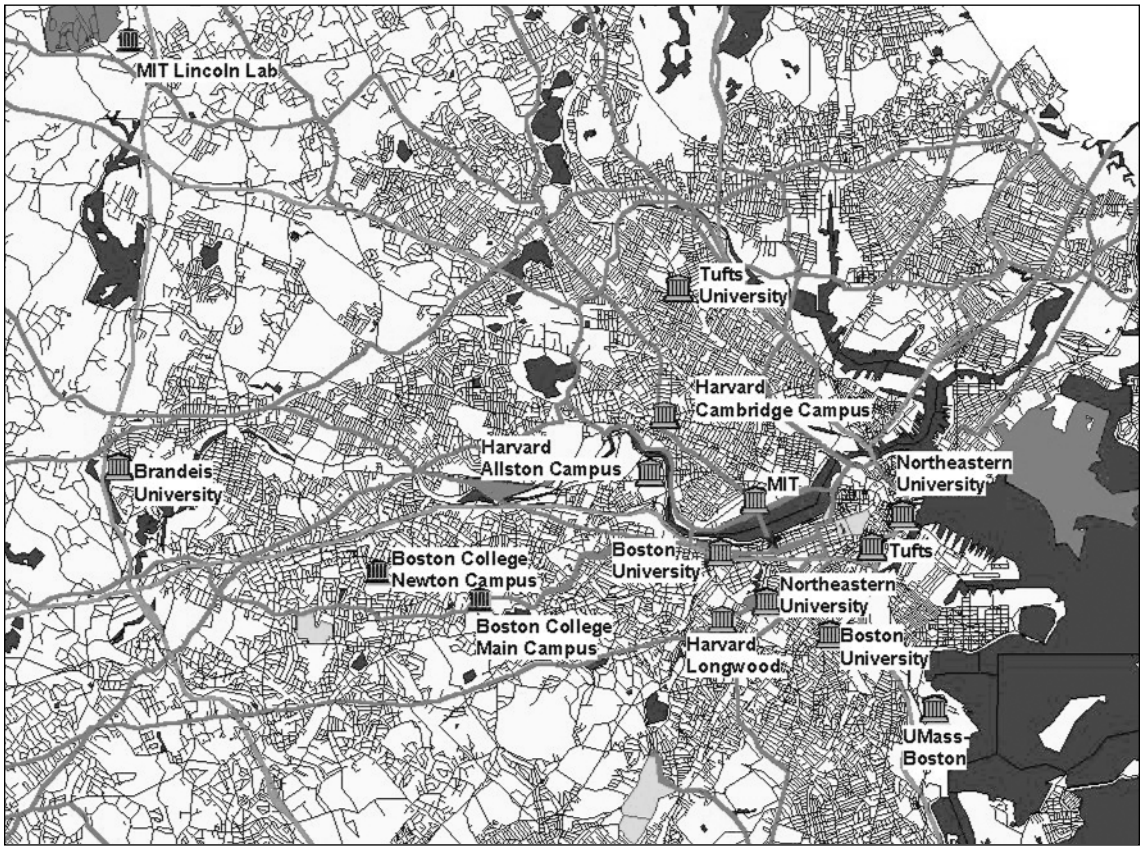
[13] For purposes of this report, we have defined the Boston area research universities as institutions located within the Route 495 loop that grant doctoral degrees, and that spend at least $10 million annually on research.

"student-centered, practice-oriented and urban," and is known worldwide for its co-operative education program. Northeastern also has one of the region's fastest-growing research programs.

Tufts University

Tufts has three campuses in Massachusetts and one in Talloires, France. The University's main campus straddles Medford and Somerville. Its schools of medicine, dentistry, biomedical science and nutrition are located in Boston, and its school of veterinary medicine — the only such school in New England — in Grafton. In several specialized areas — including international relations, nutrition and veterinary medicine — Tufts' programs are among the best in the nation. Tufts is also noted for its emphasis on teaching and learning in its undergraduate, graduate and professional schools.

Figure 2:
The Universities' Principal Boston-Area Locations



University of Massachusetts Boston

The University of Massachusetts Boston, the only public institution among the eight research universities, is located at Columbia Point. UMass Boston has a distinctly urban mission, focusing on the education of the residents of Boston and other nearby cities, and on issues that range from the improvement of city school systems to protecting the quality of urban harbors. The University also operates a center for continuing education in Plymouth.

As depicted in Table 1, the range of undergraduate, graduate and professional specialties offered by the eight universities is quite broad. In addition to a full range of undergraduate and graduate programs in the liberal arts and sciences, the universities include seven business schools, five engineering schools, three medical schools, four law schools, five schools of public and international affairs, five schools of nursing, as well as schools of dentistry, veterinary medicine, architecture and design, divinity, social work and nutrition.

Table 1
Degree-granting Programs

	Boston College	Boston Univ.	Brandeis	Harvard	MIT	Northeastern Univ.	Tufts	UMass-Boston
UNDERGRADUATE								
Arts & Sciences	■	■	■	■	■	■	■	■
Engineering		■		■	■	■	■	
Education	■	■				■		
Business	■	■			■	■		■
Nursing	■					■		■
Allied Health Professions	■	■				■		
GRADUATE/PROFESSIONAL								
Arts & Sciences	■	■	■	■	■	■	■	■
Engineering		■		■	■	■	■	
Architecture and Design				■	■	■		
Education	■	■		■		■	■	■
Public/International Affairs		■	■	■	■	■	■	
Divinity		■		■				
Business	■	■	■	■	■	■		■
Law	■	■		■		■		
Medicine		■		■			■	
Dental		■		■			■	
Nutrition		■					■	
Pharmacy						■		
Public Health		■		■			■	
Nursing	■					■		■
Allied Health Professions		■					■	
Veterinary Medicine							■	
Social Work	■	■						

These eight institutions together account for roughly four-fifths of the region's higher education industry.

- In fiscal year 2000, their collective revenues totaled more than $5.8 billion (Table 2).
- In 2000, they employed 48,750 people.
- Enrollment at the eight universities totaled more than 118,000 undergraduate, graduate and professional students; and they granted nearly 32,000 degrees.
- Together, the eight universities' major campuses represent an academic complex of more than 1,500 acres.

The universities are an important part of the region's economic base not only because of their total revenues and the number of people they employ, but because they also constitute a major regional "export" industry. Overall, we estimate that more than 70 percent of the universities' revenues are derived from sources outside the Boston metropolitan area — from federal and corporate research contracts, tuition payments by students who come to the Boston area from elsewhere in the U.S. and around the world, gifts from alumni and others living outside the Boston area, and endowment income.

Table 2
Revenues in 2000
(in thousands)

Harvard	$2,022,634
MIT	1,328,284
Boston University	950,379
Tufts	384,522
Northeastern	378,684
Boston College	362,648
UMass Boston	209,512
Brandeis	171,775
Total	$5,808,438

Conversely, we estimate that approximately two-thirds of the universities' collective budget is spent within the Boston metropolitan area — on salaries, wages and other payments to employees who live in the metropolitan area, on purchases of goods and services from metropolitan area vendors, and on local construction projects. ***Collectively, the universities spent in excess of $2 billion more within the Boston-area economy than they raised from local sources.***

The next part of this report examines the role that the eight institutions play in creating and maintaining the intellectual infrastructure that supports the Boston area economy.

Part Two:

The Universities as Infrastructure: *Education, Research and Business Development*

III. Developing the Region's Human Capital

Human capital — the knowledge and skills that workers accumulate through education and experience — plays a central role in determining the growth and decline of cities and metropolitan areas. Harvard Professor Edward Glaeser and his colleagues have found that between 1960 and 1990, population and income growth were closely correlated with levels of human capital endowment, as measured by the percentage of the cities' residents who were college graduates in 1960. In a later study, Glaeser has found that the relationship between human capital and economic growth persisted through the 1990's.[14]

That higher levels of education can lead to higher earnings is widely recognized. But the individuals who earn degrees are not the only beneficiaries. Education has important spillover effects. James Rauch of the University of California has found that increasing the average level of education in a metropolitan area by one grade increases "total factor productivity" by 2.8 percent. (Total factor productivity is a measure of the increase in a nation's or a region's output that results not from increasing the total volume of human labor, or total investment in plant and equipment, but from "working smarter.") In a similar analysis, Robert Lucas of the University of Michigan put the increase in total factor productivity associated with an additional year of education at 3.2 percent.[15]

The initial economic advantage that well-educated communities enjoy seems to increase over time.

> *Cities which began with a high degree of schooling had the greatest increases in the percentage of college-educated people over the past thirty years. The well-educated moved (or were born) in greater numbers where well-educated people were already located. This shift in population has resulted in a greater disparity among cities in the level of human capital.*[16]

Richard Florida of Carnegie Mellon University has looked at the implications of these and similar findings for the role that colleges and universities play in the process of regional economic development.

> *The most critical contribution of the university to economic development is talent. Talent is the key resource of the knowledge economy…Smart people do not necessarily respond to monetary incentives alone, they want to be around other smart people…The fact is that good people attract other good people, and places with lots of good people attract firms that want access to talent, creating a self-reinforcing cycle of growth.*[17]

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[14] Edward Glaeser, Jose Scheinkman and Andrei Schleifer, "Economic Growth in a Cross-Section of Cities," *Journal of Monetary Economics* (1995) pp. 117-143; Glaeser and Jesse Shapiro, Is There a New Urbanism? The Growth of U.S. Cities in the 1990's" (Cambridge: National Bureau of Economic Research Working Paper, July 2001) p. 2.

[15] James Rauch, "Productivity Gains from Geographic Concentrations of Human Capital: Evidence from the Cities," *Journal of Urban Economics*, vol. 34, pp. 398-99.

[16] Glaeser, Sheinkman and Schliefer, op. cit.

[17] Richard Florida and Wesley Cohen, "Engine or Infrastructure? The University's Role in Economic Development, in Branscomb, Kodama and Florida, op. cit., pp. 605-606.

Because highly-talented people are especially mobile, and because high-growth industries are often marked by rapid "churning" of employees, cities and regions that want to prosper in today's economy must constantly replenish their supply of talent. Colleges and universities play a central role in this process. As Irwin Feller of Penn State has observed:

> *Industrial representatives have repeatedly stated that universities' primary contribution to technological innovation lies in the training of students… Students are a means by which new scientific findings and technologically relevant knowledge are transferred from campus to firm.*[18]

Students and Alumni

In a region that boasts one of the nation's largest concentrations of college and university students, the eight research universities account for approximately 45 percent of total enrollment. As Table 3 shows, in the fall of 2000 more than 118,000 undergraduate, graduate and professional students were enrolled in degree programs at the eight institutions.

Table 3
Undergraduate and Graduate Enrollment and Degrees, 2000

	Enrollment			Degrees		
	Undergrad	**Graduate**	**Total**	**Undergrad**	**Graduate**	**Total**
Boston College	8,930	4,621	13,551	2,319	1,578	3,897
Boston University	15,305	10,131	25,436	3,772	4,058	7,830
Brandeis	3,075	1,124	4,199	694	400	1,094
Harvard	7,097	11,821	18,918	1,836	4,696	6,532
MIT	4,258	5,832	10,090	1,253	1,946	3,199
Northeastern	19,707	4,292	23,999	2,778	1,604	4,382
Tufts	4,889	3,824	8,713	1,257	1,242	2,499
UMass Boston	10,566	2,782	13,348	1,715	791	2,506
TOTAL	**73,827**	**44,427**	**118,254**	**15,624**	**16,315**	**31,939**

The Boston area's research universities attract students from communities throughout the United States and from countries across the globe. In 2000 the eight institutions drew more than 70 percent of all students enrolled in degree programs from outside the Boston metropolitan area. Because the universities in effect sell their services to households far and wide, they play a central role in making higher education one of the Boston area's leading "export" industries. They are also a magnet for talent, drawing top students and scholars from around the world to the Boston area.

[18] Irwin Feller, "The American University as a Performer of Basic and Applied Research," in Branscomb, Kodama and Florida, op. cit., pp. 82-84.

There are, however, some notable differences among the eight universities, in terms of the origins of their students. Brandeis, Harvard and MIT all draw more than 90 percent of their students from outside the Boston area. Roughly 70 percent of all Boston College, Boston University and Tufts students come from outside the metropolitan area. More than 40 percent of all Northeastern students, in contrast come from the Boston area, as do half of those enrolled at the University of Massachusetts Boston. ***Taken collectively, the eight universities thus serve both as a magnet for talent drawn from elsewhere, and as a source of educational opportunity for residents of the Boston area.***

Serving Older Students at UMass Boston

The University of Massachusetts Boston stands out among the eight universities for its particular focus on meeting the needs of older students. The University reports that 80 percent of its undergraduate students are age 22 or older — and 40 percent are age 30 or older. Half of all UMass Boston students are employed for 30 or more hours a week; and another 45 percent work part-time. To accommodate the needs of working students, the University schedules classes not just on weekdays but during the evening and on weekends as well, and operates an on-campus child care center.

In 1999-2000, the research universities collectively awarded a total of 15,624 undergraduate and 16,315 graduate and professional degrees. The disciplines in which the universities grant degrees represent virtually every field of intellectual inquiry and professional preparation. They encompass the liberal arts and social sciences; business and finance; electrical, civil, mechanical, industrial and biomedical engineering; government and international affairs; education; religion; law; and medicine, dentistry, nursing, pharmacy and veterinary medicine.

Many students from these institutions remain in the region after graduation. ***In 2001, more than 310,000 alumni of the eight universities lived in the Boston area — more than 31 percent of their combined alumni population***. At some schools, the percentage of all graduates who remain in the area is higher — nearly three quarters of all UMass Boston graduates, and half of all Boston College and Northeastern alumni live in the Boston metropolitan area.

Based on U.S. Census Bureau figures, we estimate that ***graduates of the eight universities represent more than 30 percent of all Boston area residents who have four-year college or graduate degrees.***

Linking Classrooms to Companies: Co-operative Education at Northeastern

Among all of the programs that formally link students at the eight universities to Boston area employers, none has a longer history than Northeastern's co-operative education program. Founded in 1909, "co-op" is in many respects the University's signature program. Students alternate periods of full-time classroom study with full-time, paid work assignments that typically last three or six months. By graduation, Northeastern students have typically had eighteen months of full-time experience in jobs directly related to their fields of study.

Initially designed as a way to allow working-class students to work their way through college, co-operative education has evolved over the years into a program whose primary purpose is to integrate classroom learning and related work experience. University officials suggest that with its strong emphasis on co-op education, Northeastern attracts students with a strong career orientation, who are looking for practical, hands-on learning.

Each year, the University places more than 6,000 undergraduates in more than 1,600 co-op sites, locally, nationally and internationally. Leading corporate participants in the program include John Hancock, Gillette, EMC, Raytheon, General Electric and the Boston Globe. Boston-area universities and hospitals are also among the leading employers of co-op students.

Companies and institutions derive several advantages from the co-op program. It provides a reliable source of young, motivated workers — something that can be especially valuable when the labor market is tight. The program can also serve as a highly effective recruitment mechanism — it gives employers a chance to hire college graduates who already know the company, and with whom they are already familiar.

The favorable responses of both students and employers to the co-op program is perhaps best seen in what happens when students graduate. Administrators at Northeastern's Division of Cooperative Education report that among members of the University's class of 2001 who had already lined up a job before graduation, 60 percent had been offered positions by employers for whom they had worked as coop students. In 1999, the starting salaries for graduates of Northeastern's co-op program averaged more than $38,300.

Continuing Education

In today's economy, higher education cannot be viewed as a process that ends when a student earns an undergraduate, graduate or professional degree. ***Especially in the knowledge-based industries and occupations on which the growth of the Boston area economy depends, skills and knowledge must regularly be renewed and refined.*** The eight universities represent an important resource for continuing education of the region's skilled work force.

"Traditional" continuing education.

The term "continuing education" covers a wide range of services. In its more traditional form, continuing education includes:

- Night and weekend courses for people who are pursuing degrees while working full-time;
- Single courses on a wide range of topics, taken either for career purposes or simply for personal enrichment; and
- Career-oriented certificate programs for those who have already completed college.

The range of programs that these universities offer to Boston-area residents is quite broad.

- ***Boston University's Metropolitan College*** offers undergraduate and graduate degree programs in a wide range of disciplines, as well as certificate programs in fields such as biotechnology, Internet technology, marketing, paralegal studies, real estate development, software development, software engineering, and telecommunications.
- ***Metropolitan College*** also offers a degree completion program, a Bachelor of Science in Management Studies, with concentrations in electronic commerce and technology management. The program targets managers and professionals who had previously started, but never finished, a college education.
- ***The BU College of Engineering's Late Entry Accelerated Program (LEAP)*** offers college-educated non-engineers an MS degree in aerospace, biomedical, computer, electrical, manufacturing or mechanical engineering.
- ***Boston College's James A. Woods College of Advancing Studies*** offers a master's degree in administration, bachelor's degrees in various fields and certificate programs in areas such as finance, information technology and human resources. Woods College also provides opportunities to enroll in individual courses at Boston College, either for college credit or on a non-credit basis.
- ***The Rabb School of Summer and Continuing Studies at Brandeis*** offers post-baccalaureate certificate programs in software engineering, e-commerce, bioinformatics and Web content, as well as masters degrees in software engineering and bioinformatics.
- ***The Brandeis Post-Baccalaureate Pre-Medical Program*** offers college graduates interested in careers in medicine, dentistry and other health professions an opportunity to complete required science courses.
- ***Northeastern's University College*** offers part-time studies leading to associate and bachelor's degrees in liberal arts, science, business, health professions and criminal justice.

Courses are offered at nine locations throughout the Boston metropolitan area; some are also available on-line. The College also offers part-time graduate certificate programs in bioinformatics, human resources management, knowledge management, non-profit management and strategic management.

- ***Northeastern's Lowell Institute School*** offers part-time programs leading either to bachelor's degrees in various engineering disciplines, or to associate degrees in engineering technologies.
- ***The Tufts School of Engineering*** offers a post-baccalaureate minor in computer science, and certificate programs in biotechnology, environmental management, manufacturing engineering, human-computer interaction and microwave and wireless engineering. The Gordon Institute at Tufts also offers a certificate program in engineering management.
- ***Tufts' REAL program — Resumed Education for Adult Learners*** — provides people who are at least 24 years old and have taken some college courses with an opportunity to complete an undergraduate degree.
- ***At the University of Massachusetts Boston, the Division of Corporate, Continuing and Distance Education*** offers undergraduate courses leading to degrees in 36 fields, including accounting, biology, chemistry, computer science, information technology and nursing.
- ***UMass Boston*** also offers post-secondary certificates in fields such as geographic information systems, technical writing, and Spanish-English translation, and post-baccalaureate certificates in database technology, Web design, and Microsoft and Oracle systems administration.

Post-baccalaureate certificate programs represent a growing segment of the continuing education market in the Boston area. Programs that help people prepare for (or advance in) careers in information technology, biotechnology and other leading industries have proven especially popular. Such programs took on increasing importance in the late 1990's, as the region faced a severe shortage of qualified professionals in fields such as computer science, web design and biomedical engineering.[19] While the recession has temporarily dampened demand, the region's long-term prosperity depends on its ability to prepare educated people for work in these fields.

Certificate programs also provide a degree of flexibility not usually available in the development and management of formal degree programs, in that they can be developed relatively quickly to respond to emerging needs. For example, rapidly-growing interest among both employers and employees in more effectively balancing work and family life recently led Boston College's Carroll School of Management to launch the nation's first certificate program in work-life management. The Carroll School also offers the nation's only certificate program on corporate social responsibility.

[19] Paul Harrington and Neeta Fogg, "Threats to Sustained Economic Growth: Science, Engineering and Information Technology Labor Shortages in the Massachusetts Economy," Northeastern University Center for Labor Market Studies/Massachusetts Technology Collaborative, September 2000.

Extending Opportunities for Learning

The Harvard University Extension School, founded in 1909, offers one of the most popular programs of continuing education in the Boston metropolitan area. The Extension School provides opportunities for area residents to earn undergraduate and masters degrees through part-time study, to obtain post-baccalaureate certificates, and to take individual courses — either for career purposes or for personal enrichment.

During the 1999-2000 academic year, the Extension School offered 550 courses in fifty different fields of study. The majority of these courses are taught by instructors affiliated with other schools at Harvard; some of these instructors provide to Extension School students at night virtually the same courses that they teach to full-time students during the day.

In addition to associate and bachelor's degrees, the Extension School offers master's degrees in liberal arts and in information technology. Its seven certificate programs, typically requiring a sequence of eight courses, prepare students who already have college degrees for careers in a variety of fields — applied sciences, administration and management, public health, museum studies, environmental management, publishing and communications, and educational technology. In each of these fields, several concentrations are typically available; students pursuing a certificate in applied sciences, for example, may concentrate in computer science, software engineering, multimedia or e-commerce.

The Extension School puts special emphasis on services to those it calls "students in transition," working adults who want to change careers, or advance to a higher level, stay-at-home mothers preparing to re-enter the work force, etc. Its Career and Academic Resource Center offers career counseling; workshops on preparing and applying for graduate school; and for those whose academic skills are rusty, workshops on topics such as exam preparation and use of the Internet.

For these students, the Extension School offers a relatively low-cost way to enhance skills and earning power. With tuition for individual graduate-level courses typically ranging from $1,300 to $1,750, a student can typically earn a certificate in a field such as computer science or software engineering for about $12,000. Need-based financial aid is available, and can significantly reduce this cost.

In 1999-2000, more than 13,000 individuals took advantage of the Extension School's services. Together they accounted for more than 22,000 course enrollments. The median age of Extension School students is 30; sixty percent are women, and about three-quarters already have a bachelor's degree. Students pursuing certificates or degrees accounted for only about 10 percent of all those enrolled; most people who attend take one or two courses on a non-credit basis.

In contrast to those enrolled in regular (and especially full-time) degree programs, the overwhelming majority of students in continuing education programs are Boston area residents. The contrast is perhaps most striking at Harvard, where 93 percent of all Extension School students are residents of the Boston area — almost exactly the reverse of local share of enrollment in Harvard's other schools.

While they may be better known for full-time undergraduate and graduate education, the Boston area's eight research universities are also among the region's leading providers of community-oriented continuing education. They offer working adults of all ages a chance to earn degrees and certificates that will help them prepare for new careers, and to take a wide variety of individual courses, whether for job-related reasons or for personal enrichment.

The universities, moreover, can provide access to a range of courses that may not be available at smaller two- or four-year colleges. Students at the Harvard Extension School, for example, can take not only introductory courses in Java programming, but also graduate-level courses on topics such as digital circuit design, network architecture and advanced multimedia design. Similarly, students enrolled in Boston College's James A. Woods College of Advancing Studies have access to a wide range of courses at Boston College. The universities also provide access to a variety of academic resources — libraries, labs, etc. — that may not be available in other settings.

These community-oriented programs are impressive not only for their quality and diversity but for their scale. In the fall of 2000, more than 25,000 people enrolled in non-degree programs at the eight universities.

Continuing professional education

In addition to these programs, some universities offer what can collectively be called continuing professional education programs. These typically consist of short, intensive courses for physicians, business executives and other professionals seeking to update or upgrade their skills.

Harvard Medical School's Continuing Medical Education program provides opportunities for medical professionals to update their knowledge on such topics as adolescent medicine, AIDS treatment, emergency medicine, nephrology, primary care for women and psychopharmacology. ***Boston University's*** and ***Tufts' Continuing Medical Education*** programs similarly provide opportunities for physicians and other health professionals to learn about the latest developments in a wide range of specialties. Together, the three make Boston one of the nation's leading centers for CME.

MIT's Advanced Studies Program offers graduate certificates in applied biology, computer science, engineering, and management and planning. The program, aimed at high-level working professionals, offers as many as 90 courses, most of them in an intensive one-to-two-week format. Participants also have the option of engaging in independent study programs, under the guidance of MIT faculty members.

At Harvard, the Kennedy School of Government offers a variety of special programs for executives and managers. Tufts' Fletcher School of Law and Diplomacy offers summer courses for professionals in diplomacy, international organizations, international business and journalism.

Educating Leaders for an Era of Globalization

In 2001, Tufts University's Fletcher School of Law and Diplomacy launched an innovative Global Master of Arts Program. Each year, GMAP enrolls up to forty experienced professionals from government, international organizations, non-profit institutions, international businesses and the media in a program that is designed to help participants understand, and prepare them to deal with, the changes that are reshaping the global community. In the 2001 academic year, GMAP students were drawn from twenty-one countries.

GMAP combines three two week residencies (two on campus and one overseas) with a year-long program of on-line learning. Courses cover such topics as international law and politics, international trade and finance, conducting international negotiations, global crisis management and transnational social trends.

Associate Dean Deborah Nutter, director of the program, notes that "GMAP is geared toward higher-level international affairs professionals from around the world. It gives students from the Boston area an opportunity to get to know and work closely with their counterparts in other countries, in a way they couldn't possibly do otherwise."

The concentration of graduate business schools in the Boston area has made it one of the country's leading centers for executive education — short courses, typically ranging from a few days to several months in duration, that are designed to help senior managers in various fields deepen their knowledge and sharpen their skills. Such programs are offered at Boston College, Boston University, Brandeis, Harvard, MIT and the University of Massachusetts Boston. During the 2000-2001, more than 7,000 executives participated in educational programs at these schools.

The Executive Education program at MIT's Sloan School of Management is typical of programs serving business executives. It offers fifteen courses ranging in length from two to five days on topics such as new product development, information technology management and supply chain management strategy.

In addition to "open enrollment" courses, MIT, Boston University and the University of Massachusetts Boston offer executive education courses that are tailored to the needs of particular corporate customers. The University of Massachusetts Boston's Division of Corporate, Continuing and Distance Education provides customized, on-site training for companies throughout the Boston area, including courses in project management, "lean manufacturing" techniques, marketing communications, and database administration.

Overall, continuing professional education programs at the eight universities collectively enrolled more than 70,000 participants in 1999-2000. In contrast to traditional continuing education courses, professional education programs typically attract participants from a much wider market. At the Harvard Business School, for example, 94 percent of all participants in executive education programs at come from outside the Boston area; and at MIT's Sloan School, 90 percent.

Helping Make Boston a Global City

During the 2001 academic year, the eight Boston area research universities enrolled more than 16,500 foreign students — nearly 15 percent of the schools' total enrollment. In addition, more than 5,000 foreign scholars were working at the universities.

These students and scholars help make the Boston area the country's third-leading center of international higher education, after New York City and Los Angeles. They highlight both the universities' ability to attract talent from all over the world, and their role as "export" enterprises. The eight universities are, in effect, exporting their services to countries around the world. Moreover, the presence of students and scholars from all over the world enriches the educational experience of American students at these institutions. And just like students from the U.S., some foreign students stay in the Boston area after graduation, adding to the region's store of human resources.

Perhaps the most important contribution that foreign students and scholars make to the continuing development of the region's economy, however, is their role in the creation of a dense network of institutional, personal and business relationships between the Boston area and their home countries. Strengthening such relationships is in the long run essential for securing the region's place in an increasingly integrated global economy.

These global relationships are further reinforced by students at the eight universities who spend one or more semesters studying at overseas institutions. According to the Institute for International Education, 3,166 students from the eight Boston-area research universities participated in study programs at overseas universities in 2001.

IV. The Role of Research in the Region's Economy

For the past several decades, basic research has played a central role in the growth and development of the U.S. economy. In a 1999 report, the Committee for Economic Development found that:

> *Basic research in science and engineering has made a major contribution to the growth of the U.S. economy. Economic returns on investments in basic research are very high. In addition, the returns to the nation from basic research investments are substantially higher than the returns to private firms, since advances in fundamental knowledge tend to be widely dispersed and exploited in innovations that deliver substantial economic benefits over a lengthy period.*
>
> *Without question, the most important institution in American basic research is the research university. The research university system has become the nation's largest basic research enterprise.*

CED also found that:

> *Basic research performed in major universities (and in other public and private labs) often has a large indirect impact on the economy of the regions where the universities are located.*[20]

Nowhere in the U.S. — and probably nowhere in the world — is this regional economic impact more evident than in the Boston metropolitan area. ***No other region can match the Boston area's concentration of highly-ranked research universities, affiliated research hospitals and other non-profit research institutes.***

Research at the Universities: A Sampler

The following examples only begin to suggest the depth and diversity of research conducted at the eight universities and their affiliates.

- Researchers in ***Boston College's chemistry and physics departments*** are developing molecular-scale electrical devices that use strings of DNA molecules as "wires."
- At ***Boston College's Institute for Scientific Research***, researchers are using three-dimensional imaging technologies to map changes that occur in the brain during sleep, and the effects of various drugs on the brain.
- Researchers at ***Boston University's Photonics Center*** are developing a form of "synthetic photosynthesis." By making it possible to store solar energy for later use, this chemically-based process would greatly enhance the practical uses and cost-effectiveness of solar power.
- At ***BU's Center for Remote Sensing***, researchers are using satellite imaging to identify potential underground water sources in some of the world's driest desert areas.

[20] Committee for Economic Development, *America's Basic Research: Prosperity through Discovery* (New York, 1999), pp. 2, 11, 19. CED is a national organization of corporate executives and university presidents that seeks through research and education to promote sound economic policy.

- Researchers from ***BU's Schools of Medicine and Public Health*** are studying potential connections between environmental factors and breast cancer.
- At ***Brandeis University's Ashton Graybiel Spatial Orientation Laboratory***, researchers study the effects of zero-gravity conditions on human beings and their machines, and how humans can more effectively adapt to life at zero gravity.
- Researchers in ***the Brandeis biochemistry department*** are using nuclear magnetic resonance imaging to study catalytic movement in proteins, improving their understanding of a process that could prove to be a "missing link" in drug design.
- Researchers at ***the Center on Women and Aging at Brandeis*** are studying how women age fifty and older interact with health care providers, in order to understand how varying levels of "health literacy" affect the adequacy of the care they receive.
- At ***Harvard's Center for Imaging and Mesoscale Structures***, scientists and engineers are using advanced lithography techniques to fabricate electronic devices on the scale of a millionth of a meter, and even smaller.
- Researchers in ***Harvard's department of biochemistry*** have developed new compounds that in early testing show great promise in providing more effective treatment of multiple sclerosis.
- Faculty from several different schools and departments are participating in ***Harvard's China Project***, an ongoing multi-disciplinary study of local, regional and global environmental issues associated with rapid industrialization in China.
- Scientists and engineers at ***MIT's Laboratory for Computer Science and the Artificial Intelligence Lab*** are involved in a project that promises to transform the way the world uses computers. The goal of "Project Oxygen" is to develop a new breed of pervasive, human-centered computers that are as abundant and natural to use as the oxygen in the air we breathe.
- Scientists at ***MIT's Lincoln Laboratory***, a federally-funded research and development center that specializes in the development of high-technology solutions to national security problems, are working on the development of open-air bioelectronic sensors that can quickly detect and identify biological agents, in quantities as small as a single particle.
- ***MIT's Laboratory for Manufacturing and Productivity*** has developed a technique called "three dimensional printing," a method for rapidly and flexibly producing parts, using virtually any type of material, directly from a CAD model.
- A team of faculty members and graduate students at ***MIT's Microsystems Technology Lab*** has developed a "pharmacy on a chip," a microchip that can hold minute quantities of different drugs, which can be released into the body in precise amounts at precise times.
- ***Northeastern's Microfabrication Lab*** has for a decade been a leader in the development of MEMS — microelectronic mechanical systems. Researchers have developed switches no wider than a human hair that can be used to turn electrical current on and off.
- At ***Northeastern's Center for Biotechnology Engineering*** researchers are developing a method for culturing two compounds, vinblastine and vincristine, trace amounts of which

are found in periwinkles. Both compounds have shown great promise in shrinking tumors; but extracting them in therapeutically useful quantities is hugely expensive. Finding a way to produce these compounds economically from cell cultures is the key to making them cost-effective in treating cancer.

- Based on their pioneering work on artificial sensory receptors, faculty at the ***Tufts School of Medicine and Tufts' Sackler School of Biomedical Research*** are developing an "artificial nose" that can be used in detecting land mines.
- Researchers at ***Tufts University's Jean Mayer Human Nutrition Research Center on Aging*** — the world's largest research institute of its kind — are investigating the links among nutrition, genomics, healthy aging and disease prevention. They have, for example, identified a folate compound that shows great promise as a potential treatment for osteoporosis.
- Scientists at the ***Tufts School of Veterinary Medicine*** are developing improved cloning techniques that will make it possible to use animal genetic material in the production of biopharmaceutical, food and fiber products.
- At the ***University of Massachusetts Boston, the Center for Survey Research*** has been working with Massachusetts General Hospital to track a cohort of 2,000 men over age 50, to understand better how prostate-related health issues are managed in primary care settings.
- ***UMass Boston's Urban Harbors Institute*** is working with several private companies to reduce harbor pollution by piloting the use of natural gas to fuel ferries.
- ***The New England Regional Center for Ocean Science and Education Excellence*** (NERCOSEE), a partnership of UMB's Environmental, Coastal and Ocean Sciences program, the Woods Hole Oceanographic Institute, the New England Aquarium and the National Science Foundation, works to increase public's knowledge of the ocean, and how it affects land and human activity.

How University Research Fuels Economic Growth

University-based research contributes to economic growth and development in the Boston area in a number of ways.

- Research at the eight major universities and at affiliated hospitals and research centers brought more than $2.5 billion in federal and private funding into the region in 2000, most of which is spent within the region on the salaries of researchers, support staff and administrators, lab operations and maintenance, purchase of supplies, etc. University-based or affiliated research is, in effect, one of the Boston area's leading exports.
- Studying with professors who are engaged in cutting-edge research — and for some, participating in such research themselves — can greatly enhance the quality of students' education. This experience can in turn enhance the value that university graduates bring to the region's employers.
- University research sometimes leads directly to the development of new products or the creation of new businesses.

- More broadly, because its results are widely shared, academic research helps expand and enrich the base of scientific knowledge on which technological and business innovation is built — even when this innovation is not directly linked to work being done on campus.
- Major academic research centers can help make a region a more attractive location for corporate research and development activity, and can provide a platform for collaborative work between academic and company researchers.

All of these effects are clearly visible today in the Boston area.

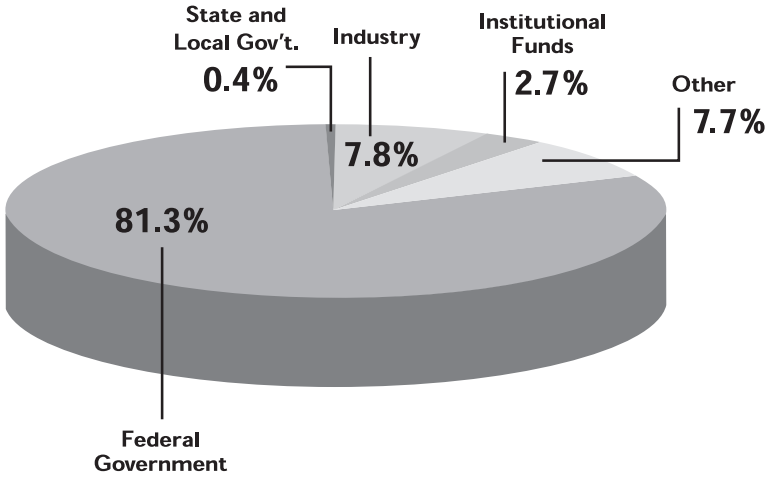
Research Expenditures at the Universities

Research expenditures at the eight universities in fiscal year 2000 totaled $1.5 billion. Together, these eight institutions accounted for more than 95 percent of all college and university research spending in the Boston metropolitan area.

More than 80 percent of all research spending at the eight universities was financed by federal government agencies, including the National Institutes of Health, the National Science Foundation, and the Department of Defense. Another 18 percent came from corporations, foundations and other private sources. ***Less than one-half of one percent of all research spending at the eight universities is financed by state or local government.***

University research activity in the Boston metropolitan area has grown steadily in recent years. Between 1995 and 2000, aggregate research spending at the eight universities grew by 25.6 percent — an average annual increase of 4.7 percent. Several of the region's smaller university research programs have registered particularly strong growth during this period. Research spending at Boston College, for example, grew by nearly 16 percent annually between 1995 and 2000, and at Northeastern by 12.4 percent annually.

Figure 3:
Sources of funds for research spending
(in $ thousands)
(aggregate, without UMass Boston)



The eight universities' direct spending on research is not, however, the only measure of their role in attracting research funding to the Boston area. Other research institutions that are either formally affiliated with one or more of the eight universities, or are located in the Boston area as a result of past ties to the universities, together accounted for an additional $383 million in federally-funded research in fiscal year 2000. Research centers currently or previously affiliated with the universities include:

- ***The MITRE Corporation,*** located in Bedford, a non-profit organization specializing in systems engineering and electronics research for the Department of Defense, the Federal Aviation Administration;
- ***The Whitehead Institute,*** Cambridge, one of the world's leading biomedical research centers;
- ***Draper Laboratory,*** also in Cambridge, a leader in the development of automated navigation and guidance systems;
- ***The Center for Blood Research,*** Boston, one of the world's leading centers for the study of inflammation and immune system response; and
- ***The Schepens Eye Institute,*** Boston, one of the world's leading centers of ophthalmic research.

Moreover, ***hospitals affiliated with Harvard, Tufts and Boston University medical schools in fiscal year 2000 received nearly $675 million in federal research funding.*** Major research hospitals affiliated with the medical schools included:

- Massachusetts General Hospital
- Brigham & Women's Hospital
- Dana-Farber Cancer Institute
- Beth Israel-Deaconess Medical Center
- Children's Hospital
- Tufts-New England Medical Center
- Boston Medical Center
- McLean Hospital
- Massachusetts Eye and Ear Infirmary
- St. Elizabeth's Hospital
- Lahey Clinic

These affiliates accounted for 63 percent of all federal research funding received by voluntary hospitals in 2000.

Equipping Tomorrow's GI's

The diversity of research strengths demonstrated by the eight Boston-area universities means that the region is well-positioned to respond as new research needs and priorities emerge. During the past year, research and development activities aimed at enhancing America's national security have provided some notable examples.

In 2002, MIT's strengths in nanoscience and technology — understanding and manipulating matter in bits as small as one-billionth of a meter, about one one-hundred-thousandth the width of a human hair — led the Department of Defense to award $50 million to MIT to assist in developing new applications of nanotechnology for military purposes. Scientists and engineers at MIT's new Institute for Soldier Nanotechnology are working on the development of fabrics that would function like an added layer of muscle, allowing soldiers to move more quickly while carrying heavy gear. Other applications include protective clothing, sensors that will provide an early warning of the presence of chemical or biological weapons, and dressings that will speed the healing of combat wounds.

A Collaborative Enterprise

Since the 1980's, the emergence of new areas of scientific research — such as genomics, proteomics, photonics, nanoscience, network science and the study of global climate change — have blurred the traditional boundaries between academic disciplines. Advancing human knowledge in these areas, and putting that knowledge to practical use, is more than ever an enterprise that requires collaboration among specialists in many different fields.

The need for collaboration across disciplines is evident not only in "hard" science, but in the social sciences as well. The continuing process of global integration, for example, has given rise to issues that can only be addressed through the combined efforts of specialists and many fields. And finding answers to some of the world's most pressing problems — from the complex challenges of global climate change to the continuing spread of AIDS — is likely to require intensive collaboration among experts in the physical, life and social sciences.

The breadth of their research strengths means that the Boston-area universities are especially well-equipped for leadership in an era of collaborative science. At ***MIT's Nanomechanical Technology Lab***, for example, faculty members and graduate students from the departments of materials science, mechanical engineering, chemical engineering, electrical engineering and computer science, bioengineering and aeronautics are working together to understand how the behavior of materials changes at nanoscale, and how it can be manipulated more effectively.

At Brandeis, the ***Rosenstiel Basic Medical Sciences Research Center*** similarly brings together biologists, physicists, chemists and biochemists in what the University calls "a uniquely interdisciplinary approach to combating disease." The Rosenstiel Center's building features an open architecture designed to eliminate barriers and facilitate collaboration among research groups.

Moreover, the unique concentration of major universities in the Boston area, and their diverse strengths, create unparalleled opportunities for collaboration across institutional lines. In some cases, such collaboration is formalized through the establishment of joint research centers. The ***Harvard-MIT Division of Health Sciences and Technology*** serves as both "magnet and infrastructure" for research that combines basic science, medicine and engineering. Major areas of research at HST — which brings together not only the strengths of Harvard and MIT, but also those of seventeen affiliated hospitals and research institutes — include biomedical imaging, regenerative technologies and cardiovascular technologies.

The Silvio Conte Center for the Neuroscience of Mental Disorders, a research center devoted to studying the biological basis of schizophrenia, is similarly a collaborative undertaking. The Conte Center, which is funded by the National Institute of Mental Health, brings together researchers from Brandeis, Harvard Medical School, Boston University, the Massachusetts Department of Mental Health, the Brockton VA Hospital, Massachusetts General Hospital and McLean Hospital.

Collaboration can also be supported through less formal mechanisms. For example, the ***Inter-University Committee on International Migration*** has for thirty years provided a major regional forum for study and discussion of issues relating to immigration and the status of refugees. The Committee includes scholars from Boston University, Harvard, MIT and Tufts, and also Wellesley College.

Collaboration across institutions is not just a regional phenomenon. More and more research is being conducted through nationwide and even international networks. ***Northeastern's Center for Subsurface Sensing and Imaging Systems*** (CenSSIS) — one of a network or engineering research centers funded by the National Science Foundation — is actually a collaborative effort that also includes Boston University, Massachusetts General Hospital, the Woods Hole Oceanographic Institute, Rensselaer Polytechnic Institute, Memorial Sloan-Kettering Cancer Center, Mayaguez University in Puerto Rico, Lawrence Livermore National Laboratory, and the Idaho National Engineering and Environmental Laboratory.

University-Industry Research Partnerships

Collaborative research is not limited to the universities and their non-profit affiliates. The eight universities also contribute to the economic vitality of the Boston area through a dense and growing network of research partnerships with companies throughout the region.

Since the 1980's, companies have for a number of reasons shown increasing interest in collaborative research. In many industries, technological developments are occurring too rapidly, and cut across too many disciplines, to be managed effectively with in-house research staff alone. Many large corporations, moreover, sharply reduced their own R&D operations during the recession and downsizing of the early 1990's; and many of them chose during the recovery that followed not to rebuild those operations.[21] At the same time, small and mid-sized firms find that collaborating with university researchers can be a way to leverage their own limited resources.

[21] Lita Nelsen, "The Rise of Intellectual Property Protection in the American University," *Science*, March 6, 1998, pp. 1460-61.

Here we will highlight just a few of these partnerships.

- ***The Leaders for Manufacturing (LFM) Program,*** founded in 1988, is a joint program of MIT's School of Engineering and Sloan School of Management. Faculty and students at LFM work with corporate and academic partners through team projects and internships to improve manufacturing operations. LFM partners with manufacturing facilities in the Boston area include Axcelis Technologies, Compaq, Eastman Kodak, Genzyme, H.C. Stark, Intel, Motorola, Philips Electronics, Raytheon, Sun Microsystems and Teradyne.
- ***Boston University's Photonics Center***, founded in 1994, provides a base for collaboration between the Center's corporate partners and members of the university community in the development and application of photonics technology — the "practical application of light." Corporate partners work with BU faculty and students at the Center's $80 million, 235,000 square-foot facility, which includes state-of-the-art labs, meeting rooms, lecture halls and incubator space for start-up companies.
- ***The Fraunhofer-Boston University Center for Manufacturing Innovation*** is a partnership between the University and the Fraunhofer Institute, Europe's largest industrial research organization. The Center works with industry clients to provide innovative solutions to practical problems, such as the design of customized micromachining processes, and the use of "rapid prototyping" to accelerate the progression of new products from design to production. The Center's 17,000 square-foot facility provides both space for R&D work and a "manufacturing floor under laboratory conditions." In addition to the assistance it provides to client companies, the Center offers BU students an opportunity to work on real-world engineering problems.
- ***Northeastern's Center for Subsurface Sensing and Imaging Systems (CenSSIS)*** is working on the application of digital imaging technologies to a wide range of subsurface diagnostic and analytic problems, in areas as diverse as medical care and highway maintenance. Major partners include Raytheon, Mercury Computer Systems, Boston Scientific and Analogic.
- ***The Barnett Institute*** at Northeastern, established in 1973, conducts research and trains students in analytical chemistry and biotechnology. The Institute's researchers work closely with a network of industry affiliates, including Applied Biosystems, Genentech, Genome Therapeutics and Pfizer.
- ***Harvard's Institute for Chemistry and Cell Biology (ICCB)***, founded in 1997, is a joint venture of the Harvard Medical School and the University's Faculty of Arts and Sciences, in partnership with Merck, Germany's Merck KGaA, and the National Cancer Institute. ICCB is engaged in the development of chemical "tools" used in dissecting biological processes at the cellular level. These tools can be used both in basic research, and as starting points in the development of new therapies. Housed in 12,000 square feet of newly-renovated space on the Harvard Medical School Quadrangle, ICCB supports the work of fifty research associates, graduate students and visiting corporate scientists.

Helping Companies Find Profits in a Cleaner Environment

Founded in 1995, University of Massachusetts Boston's Environmental Business Technology Center aims to help entrepreneurs throughout the greater Boston area get the resources they need to develop their businesses. Staff and faculty members affiliated with the Center have, for example, have worked with SolmeteX, a Walpole-based company that applies advances in separation technology to problems of industrial waste treatment. A UMass faculty member helped the company analyze problems of mercury contamination generated by hospital laboratories. Based on this knowledge, the company was able to develop wastewater treatment systems that a major manufacturer of hospital lab equipment has incorporated into its products, generating an estimated $10 million in sales for SolmeteX.

In collaboration with engineers from UMass Lowell, the Center also helped CASTion Corporation, based in Ludlow, redesign its system for recovering and reusing chemicals from industrial wastewater. Center staff then helped the company obtain EPA certification of its new Controlled Atmosphere Separation Technology (CAST) system as a "totally enclosed" waste treatment system, exempt from federal permitting requirements under the Resource Conservation and Recovery Act. This certification led to a significant increase in sales of the CAST system, and enabled CASTion to attract new investment.

- ***The Center for Corporate Citizenship at Boston College's Carroll School of Management*** works with more than 350 corporate partners to promote recognition of corporate social responsibility as an essential component of modern business management, and to identify and promote adoption of best practices in corporate citizenship. The Center's members include major Boston-area companies such as Blue Cross-Blue Shield of Massachusetts, EMC, Fidelity Investments, FleetBoston Financial, Gillette, Novartis and Raytheon.
- Since 1997, scientists at the ***Tufts School of Veterinary Medicine*** have collaborated with researchers at Cambridge-based Genzyme Transgenics in the development of animal cloning techniques. In 1999 the Tufts-Genzyme team succeeded in producing the world's first cloned transgenic goats. The goats are being used to produce an anti-clotting protein that could in the future be of great value in treating cardiac patients.
- In 2001, a team of faculty members at the ***Tufts School of Engineering*** began collaborating with a major consumer electronics company on the development of the next generation of rechargeable batteries. The ***Tufts Bioengineering Program*** also conducts collaborative research programs with industry partners.
- At the University of Massachusetts Boston, the ***Greater Boston Manufacturing Partnership*** helps small and mid-sized manufacturing companies improve productivity and compete more effectively through the adoption of "continuous improvement" techniques. In 2001-02 the Partnership worked with 75 Boston-area firms, and provided training to 5,000 company employees.

Student Participation in University Research

One of the most important ways in which university research contributes to the strength of the regional economy is by enriching the education of both undergraduate and graduate students. Working side by side with senior faculty members on major research projects is a standard feature of graduate education in the U.S.; it is, in fact, one of the distinguishing strengths of the American approach to graduate education. Participation in cutting-edge research doesn't just enhance grad students' educational experience — it turns them into instruments of technology transfer.

> *Students are a means by which new scientific findings and technologically relevant knowledge are transferred from the campus to the firm. Indeed, as new technologically relevant research findings become embedded in the tacit know-how of students….their importance of technology transfer agents is likely to increase.*[22]

While graduate student involvement in research may be a common feature of the American university system, one of the great advantages that the Boston area derives from its concentration of major research institutions is the extraordinary opportunity it creates for undergraduates as well to participate in major research projects.

MIT has been a pioneer in undergraduate involvement in high-level research. The Institute's ***Undergraduate Research Opportunities Program*** (UROP), founded in 1969, gives students a chance to work collaboratively with faculty and research staff, either by joining an existing project or proposing entirely new projects of their own. Roughly 80 percent of all MIT students complete at least one UROP project during their undergraduate years.

UROP students gain experience in all phases of the research process — project planning, proposal writing, conducting research, analyzing data, and presenting results both orally and in writing. Projects may last anywhere from a semester to a year. Some projects are done for academic credit, some as part-time paid employment, and some on a volunteer basis. Upon completion, projects are evaluated by faculty sponsors and by the students themselves.

Like MIT's program, ***Boston University's Undergraduate Research Opportunities Program*** provides students with a wide range of opportunities to conduct their own research projects, under the supervision and guidance of BU faculty members. In addition to working on their projects, participating students attend periodic lectures and workshops on topics such as research methods, obtaining grants and academic publishing. When projects are completed, students may present their results at BU's annual university-wide research symposium; and some formally publish the results of their work in academic journals.

In keeping with its emphasis on cooperative education, Northeastern arranges placement of students in research work through its ***Industrial Research Opportunities Program.*** Co-op students might, for example, be placed with one of the industrial partners at CenSSIS or the Barnett Institute — and then be detailed by the company to work on a collaborative research project at the Center or Institute. Such arrangements can help students gain an especially valuable understanding of collaborative research from the corporate perspective.

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[22] Irwin Fellner, op. cit., p. 84.

The Harvard College Research Program provides funding for student-initiated, faculty-supervised research projects. HCRP funds can be used to pay for travel or other research expenditures, or to pay wages to students who are not receiving academic course credit for their work. Awards typically range from $750 to $1,000 for projects undertaken during the academic year, and $1,000 to $2,500 for summer projects. Harvard's Faculty Aide program also provides 50-50 matching grants to encourage faculty members to hire undergraduates as research assistants.

Breaking New Ground at Brandeis

In part because of the large scale of its research enterprise relative to its undergraduate student enrollment, Brandeis offers its students an unusually broad array of opportunities for participation in high-level research projects. For example, based on work he had done with Professor John Lisman in an introductory neuroscience course, Daniel Abadi ('02) developed a groundbreaking computer simulation of the biological processes involved in memory storage. He then had the opportunity to apply what he had learned in a different field; working with Assistant Professor of Computer Science Mitch Cherniak, Daniel developed a new tool to be used in designing retrieval procedures in large-scale databases.

As a result of his creative work in neuroscience and computer science, Daniel was awarded the prestigious Churchill Scholarship, which will allow him to do graduate work in engineering at Cambridge.

At Boston College, the ***Undergraduate Faculty Research Fellows*** program provides financial assistance to students who work on faculty research projects. During 2002, 267 undergraduates were paid an average of about $1,500 for their work on a wide range of projects.

At Tufts, the ***Undergraduate Opportunities Research Fund*** each year provides support to 50 to 75 liberal arts and engineering students who engage in research under the supervision of a faculty member.

The University of Massachusetts Boston also encourages undergraduate participation in faculty-sponsored research projects. John Warner, professor of chemistry at UMass Boston, recently commented on how research work helps students prepare for work beyond the classroom:

> *In research, the benefit of looking at a problem from a variety of perspectives becomes obvious. Classical courses often give students the impression that science is organized into several isolated "groupings" of disciplines. Research experiences underscore how the sciences are interconnected. Students are often surprised initially at how useful things they have learned from a variety of classes are to their research projects. In addition to technical skills required to perform specific tasks, time management, communication and teamwork skills are simultaneously developed during research experiences.*

A Magnet for Corporate Research Activity

Both economists and local economic development practitioners have long recognized the contribution of companies "spun-off" from university laboratories to the growth of regional economies. This type of university-based business development is discussed below, in Part Five.

Beyond these spin-offs, however, concentrations of excellence in university research can also foster regional economic development by attracting investment in research facilities and activities by large global and national companies. Merck & Co., for example, is now developing a 400,000 square-foot research center on the campus of Emmanuel College, adjacent to the Longwood medical area. When it is completed in 2004, Merck's Longwood Biomedical Research Facility will employ approximately 300 scientists, administrators and support staff. At a groundbreaking ceremony in October 2001, CEO Raymond Gilmartin stated that Merck had chosen the Longwood site because it wanted to be part of "the Boston research community." Janet Skidmore, Merck's director of public affairs, says that the company's choice for the location of its new facility "says a great deal about our ability to recruit top scientists and attract top talent." The Boston area, she says, "is home to one of the finest biomedical communities in the world."

AstraZeneca, one of Europe's largest pharmaceutical companies, moved into a new complex in Waltham in April 2000. AstraZeneca VP Hans Nilsson explained what drew the company to the area. "There's basic science research going on in the universities, clinical research going on in the hospitals. It's a fantastic, talented pool from which to draw people and resources."[23] Pfizer's Technology Discovery Center, opened in Cambridge in 1999, similarly seeks to capitalize on the region's strengths. Other major pharmaceutical and biomedical companies that have opened research facilities in the Boston metropolitan area in recent years include Amgen, Aventis, Eisai, Wyeth, and Serono.

In May 2002, Novartis announced that it would join the migration of major life science companies to the Boston area by moving its worldwide research headquarters from Basel, Switzerland, to Cambridge. Novartis CEO Daniel Vasella said:

> *We have to go where the talent is. The talent doesn't come to us. We want to be in an environment where there's a lot of young scientific talent, where we can establish networks with academia and hospitals.*

After initially leasing space in a Tech Square commercial building developed by MIT, Novartis announced plans to lease the former NECCO manufacturing plant in Cambridge, and convert it to labs and office space. The company will initially employ 400 researchers in Cambridge with plans to grow to 1,000 within five years.[24]

A similar pattern can be seen in the information technology sector. Sun Microsystems has major operations in Chelmsford. Cisco Systems employs 2,100 people at locations in Chelmsford, Franklin, Acton, Lexington and Lowell; and has three buildings under construction at a new office campus in Boxborough. Cisco officials have characterized the new

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[23] Naomi Aoki: "State of Biotech," *Boston Globe*, September 27, 2000.

[24] Naomi Aoki and Jeffrey Krasner, "A New Kind of Hub," *Boston Globe*, May 8, 2002.

campus, where they have approvals for the development of up to 1.5 million square feet of space, as a "second home" for the San Jose-based company. In 2002 Orange SA, one of Europe's largest wireless communications companies, opened a new research center is Cambridge.[25]

It is worth noting that in most of the cases, no special state or local government incentives were needed to attract major corporate investments. The strength of the Boston area's research complex was enough.

The words of Richard Florida cited in Part IV apply to corporate decision-makers as much as they do to individuals: Smart people do not necessarily respond to monetary incentives alone; they want to be around other smart people.

America's Most Research-Intensive Region

The strength of the eight research universities, and their success in stimulating private R&D investment, have helped make the Boston metropolitan area the nation's most research-intensive regional economy. Brandeis economist Adam Jaffe has estimated that academic, non-profit and corporate research spending in Massachusetts represents nearly 6 percent of the Commonwealth's gross state product. Michigan ranked second, with research spending equaling 4.7 percent of gross state product.[26]

To understand the role that research plays in the Boston area economy, it is important to recognize that it is not the preserve of any one university — or even of the research universities as a group. ***Academic research is especially effective as an engine of economic growth in the Boston area precisely because it takes place not in an ivory tower, but in a complex network of relationships among universities, hospitals, other affiliated institutions, corporations and entrepreneurs.*** Through the historic role they played in fostering the growth of this network, and because of their continuing role in sustaining it and fueling its continued growth, the eight research universities provide the Boston area with an enduring source of economic strength and competitive advantage — one that few if any communities in the world can match.

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[25] *Boston Globe*, March 28 2002.

[26] Douglas Jamison and Christina Jansen, "Technology Transfer and Economic Growth," The Journal of the Association of University Technology Managers, vol. XII, 2000 (www.autm.net.pubs.journal)

V. The Universities' Role in Business Development

Helping to generate and grow new businesses is one of the most commonly cited ways in which universities support regional economic development. There are a number of ways in which the eight Boston area research universities have contributed to this process.

- Licensing of new technologies first developed in university labs to local start-up companies.
- Providing a variety of other supports to start-up or early-stage companies — new business incubator facilities, business support services, and venture capital investments.
- Faculty participation in the development of new businesses.
- Development of new businesses by university graduates.
- Development of commercial office and research space needed to accommodate the continued growth of new companies.

Licensing University Technology

The licensing of technologies to commercial enterprises is perhaps the most directly measurable way in which academic research can be translated into economic growth. The movement toward licensing university technology began in earnest in the 1980's, after Congress enacted the Bayh-Dole Act. The law clarified universities' right to patent, license and collect royalties on products of federally-funded research.

An incentive for economic development

The licensing function contributes to long-term economic growth in several ways.

- Licensing gives universities and companies a financial incentive to expedite the movement of research findings from the lab to the marketplace. Since the enactment of Bayh-Dole, Douglas Jamison and Christina Jansen have found that the number of universities with active "technology transfer" programs has increased eightfold, to more than 200. There has also been a steady increase in what they call "middle-ground" university research — further work that is often needed before the findings of basic research can begin to attract private investment.[27]
- Licensing allows academic researchers — who typically receive a share of the royalties the universities collect — to profit from their work.
- Licensing provides a stream of revenue that is used in part to support further research. Some universities use licensing revenues specifically to support the type of "middle-ground" research that Jamison and Jansen say is so essential to realizing the full economic value of basic research.

Some Boston-area universities — including MIT and Boston University — had already been actively involved in technology transfer before the enactment of Bayh-Dole. Others

[27] Lori Pressman and Don Kaiser, "Measuring Product Development Outcomes of Patent Licensing at MIT," February 2000 (web.mit.edu/tlo/www/presentations)

established formal technology transfer programs during the 1980's; and some not until the 1990's. (At the University of Massachusetts, the technology transfer function is managed centrally for all campuses.) Typically, university technology transfer policies require faculty members and others to disclose any invention or discovery resulting from work done at the university. The technology transfer staff will determine whether the university should apply for a patent. If the invention appears patentable, they will begin the process of making it available for licensing, either to an established company or to a new venture established specifically for the purpose of bringing the new technology to market.

MIT's policy governing the distribution of licensing income is typical of the policies followed by most research universities, and illustrates the incentives for commercial application of university research that have been created under Bayh-Dole. After recovering costs associated with obtaining a patent, MIT's Office of Technology Licensing retains 15 percent of the royalties paid by the licensee, to cover its own costs. The remaining income is split three ways — one-third to the inventor, one-third to his or her academic department, and one-third to MIT's general fund. This allocation gives individual researchers a powerful incentive to pay attention to possible practical applications of their work, and to cooperate in efforts to realize that potential. It also gives MIT's academic departments an incentive to encourage and support faculty entrepreneurship.

The role of the technology transfer staff in the licensing process is not limited to marketing new technologies, negotiating agreements with licensees, and collecting royalties. Following the "use it or lose it" precept, they are also responsible at many universities for monitoring the licensees' activities, to ensure that the companies are working diligently to bring to market the technologies first developed in university labs. As one technology transfer officer has observed, "MIT's nightmare is that we license the cure for cancer, and it sits in the licensee's filing cabinet." MIT's licenses typically include specific benchmarks that licensees are required to meet, such as funds spent in developing the technology, specific technical milestones, target dates for bringing a product to market, and initial sales goals.

Developing new Boston-area businesses

In 2000, the eight private research universities collectively executed 280 licensing or option agreements for use of technologies initially developed on-campus. The licensees included 41 new companies that were created specifically to develop further and bring to market technologies first developed at the universities.

Table 4:
Technology Transfer Activity at Boston Area Research Universities, 2000

Licensing Income (000s)	US patent applications filed	US patents issued	Licenses/ Options grants	Start-up companies formed
$44,498	**620**	**264**	**280**	**41**

Source: The Chronicle of Higher Education, Universities

Although the universities license technology to companies throughout the U.S. and abroad, licensees are to a significant extent concentrated in the Boston area. This is especially so in the case of technologies licensed to start-up companies; the majority of start-ups based on university research are usually located, at least initially, near the university campus.

As of 2001, there were 112 companies in the Boston metropolitan area that had been started with technologies licensed by the eight research universities — most of them within the past decade. Just as local "angel" investors, banks and private equity firms helped provide the financial capital these firms needed to get off the ground, the research universities provided the intellectual capital. Table 5 highlights some of the more notable examples.

Table 5:
Licensed Boston-Area Start-Ups: Examples

Company	Location	Year Founded	License from	Area Employees
American Superconductor	Westborough	1987	MIT	340
SpeechWorks International	Boston	1994	MIT	400
Akamai	Cambridge	1998	MIT	800
E-Ink	Cambridge	1998	MIT	115
Cetek	Marlborough	1996	Northeastern	100
Jarg Corporation	Waltham	1998	Northeastern	5
People's Genetics	Woburn	2000	Northeastern/MIT	25
Point Therapeutics	Boston	1996	Tufts	10
Paratek Pharmaceuticals	Boston	1996	Tufts	78
Ion Signature Technologies	Cambridge	1999	Tufts	6
InfoLibria	Waltham	1997	Boston U	100
Transkaryotic Therapies	Cambridge	1988	Harvard	340
Ariad Pharmaceuticals	Cambridge	1991	Harvard/MIT	60
Boston Life Sciences	Boston	1992	Harvard	13
Zycos	Lexington	1994	Harvard	25
Syntonix Pharmaceuticals	Waltham	1999	Brandeis	50

It often takes five years or more before new companies begin to generate significant revenues. Nevertheless, recently-licensed companies may already be making a significant contribution to the vitality of the region's economy, by attracting substantial new investment by venture capital firms or major corporations. Studies conducted at MIT, the University of Pennsylvania and Ohio State University have all found that pre-production investments in technologies licensed from the universities averaged approximately $1 million per year per license.[28] ***If we assume an average pre-production investment period of five years, then we can estimate that over a span of five years, the 280 technology licenses granted by the Boston-area universities in 2000 will generate $1.4 billion in new investment.***

[28] Douglas Jamison and Christina Jansen, "Technology Transfer and Economic Growth," The Journal of the Association of University Technology Managers, vol. XII, 2000 (www.autm.net.pubs.journal)

In some cases, of course, investments in the commercialization of university technologies far exceed the average of $1 million per year. For example:

- ***Axsun Technologies*** is a developer and manufacturer of photonic subsystems used by optical equipment suppliers, launched in February 1999 using technology licensed from MIT. During its first two years, the company attracted a total of $157 million in equity and debt financing.
- ***E Ink***, a developer of electronic printing applications started in 1998 with technology licensed from MIT, has attracted more than $100 million in venture capital and other private equity financing, and has entered into a joint venture with Philips Components.
- ***InfoLibria,*** a provider of Internet content distribution systems, was founded in 1997 with technology licensed from Boston University. During its first four years, InfoLibria attracted $115 million in private equity investment, and recently negotiated a partnership with Microsoft.
- ***Paratek Pharmaceuticals*** was established in 1996 to develop further and bring to market new approaches to overcoming bacterial resistance, first developed at Tufts. During its first five years, Paratek attracted more than $64 million in equity investment from private sources and from GlaxoSmithKline.
- ***Syntonix Pharmaceuticals, Inc.,*** founded in 1999 with technology licensed from Brandeis University, is developing methods for oral, nasal and pulmonary delivery for large-molecule drugs across mucosal barriers. It has to date attracted more than $49 million in equity investment.

Support for Start-Up Companies

In addition to licensing technologies first developed in their laboratories, several Boston area universities provide more direct support to start-up and early-stage ventures. Both ***Harvard's Office of Technology Licensing*** and ***BU's Community Technology Fund*** provide grants that are designed to help faculty members bridge the gap between research and commercialization — for example, by supporting the building of a prototype. Between 1999 and 2001, CTF provided fifteen such grants, ranging from $25,000 to $75,000.

At BU, as projects move closer to the marketplace, CTF will in selected cases provide additional support — modest investments of seed capital, help in finding a start-up CEO, and assistance in arranging financing. In a few cases, CTF's New Ventures unit has itself provided an interim CEO.

MIT's Technology Licensing Office similarly gives inventors advice about whether a new technology can provide the basis for a viable business; introduces them to potential investors, potential CEO's and others whose help they will need in getting a business off the ground; and provides advice on a variety of other issues.

MIT's new ***Deshpande Center for Technological Innovation,*** launched in 2002 with a $20 million gift from Sycamore Networks founder Desh Deshpande, has taken this support a step further. Over a five-year period, the Center will provide at least $15 million in grants to MIT

faculty and students to support work aimed at bridging the gap between promising academic research and the first stage of commercial development. "Ignition" grants provide up to $50,000 for work still in the conceptual stage; "Innovation" grants provide up to $250,000 for more advanced development work.

Like its counterparts at BU and MIT, ***Tufts' Office of Technology and Industry Collaboration*** provides a full range of services to faculty members and students interested in starting companies with technology licensed from the University, and also consults with other members of the university community as well.

Helping Small Businesses Grow at Boston College

The assistance that Boston-area research universities provide to aspiring entrepreneurs is not limited to members of the university community, or to companies spun out of university research labs. Boston College's Small Business Development Center provides one-on-one counseling, seminars and workshops for new, growing and troubled small businesses, covering topics such as small business finance and accounting, business planning, and marketing and advertising.

Several years ago, for example, the Center received a request for help from Rosi Amador, a singer in a Latin band. With two small children, Amador wanted to spend more time at home, but stay in the music business. SBDC staff helped her start and develop Music Amador, a booking service for Latin music acts that she now runs from her home in Cambridge. The Center's services have included providing a team of four graduate students who helped Amador analyze her market and refine her marketing strategy.

Boston College's SBDC, which was founded in 1980, has a full-time professional staff of four, and also uses and faculty and students from the Carroll School of Management. Each year, the Center gets about 800 requests for assistance — some from home-based start-ups like Music Amador, and some from fast-growing technology firms.

Tags: We're It

Sometimes the research universities' role in business development goes well beyond supporting the creation of individual companies. The rapid development of radio-frequency identification technology offers a notable example.

Radio frequency identification (or RFID) technology has been around for some time. Millions of drivers, for example, now use it every day to pay highway, bridge and tunnel tolls. The real advance in RFID, however, occurred just a few years ago, with the development of tiny, low-cost silicon-chip transponders. Chip-based "tags" as small as a grain of sugar and as cheap as five cents each will in the next few years be embedded not just in all kinds of packaging, but directly in many types of goods as well. Tagging will enable companies to manage their inventories and control their supply chains much more effectively. Industry estimates suggest that over time, widespread adoption of RFID tagging could reduce supply chain costs by 6 to 10 percent.

In 1999, Professor Sanjay Sarma and Director Kevin Ashton created the Auto-ID Center at MIT, with the goal establishing common standards for the use of RFID, and promoting continued research and development. The Center very quickly became the hub for a worldwide network of companies — major manufacturers, transportation companies, retailers, semiconductor firms and others — that are working to make RFID tagging an everyday reality. In doing so, the Center and its partners are in effect building a major new component of the infrastructure of commerce.

Several Boston area companies have from the beginning worked very closely with the Auto-ID Center; Gillette was among its earliest and most active corporate sponsors, and it remains among the leaders in the testing and commercial use of RFID. Beverly-based Sensitech — one of the leading providers of specialized systems for refrigerated supply chain management — is also a major sponsor. Several recent start-ups — such as ThingMagic, founded in 2000 by five MIT graduate students — are also working closely with the Center to refine tagging technology.

The uses of tagging technology are not limited to supply chain management. Boston-based GenuOne, founded in 1998 by Boston University grad Jeffrey Unger, is a leader in the use of tagging to authenticate products and prevent counterfeiting. The company's Intelligent Access Control System, designed to improve airport security, is currently undergoing its first pilot test at Logan Airport.

GenuOne also illustrates how one generation of entrepreneurship can beget another. The firm has created a venture financing arm that has invested $1 million in PhotoSecure, a recent Boston University "spin-out" housed in the new business incubator at BU's Photonics Center. Rather than RFID technology, PhotoSecure uses photochemical "ink" to tag products and prevent counterfeiting.

The role of MIT's Auto-ID Center and BU's Photonics Center shows how academic researchers, established companies and entrepreneurs can together combine to create not just new products and new ventures, but an emerging new industry — one in which the Boston area is already well-positioned for growth.

Incubators and Investments

Several Boston-area universities operate incubator facilities that provide pre-built space and support services for new ventures.

- ***BU's Photonics Center*** includes 23,500 square feet of incubator space, enough to house up to fourteen start-up companies. In addition to flexible space, the incubator provides access to the Center's laboratories and equipment, meeting space, and access to business services such as legal, accounting and PR services.
- ***BU's Biosquare II*** building (described below) includes the Innovation and Discovery Center, a 12,000 square-foot incubator that can accommodate six biotechnology start-up companies.
- ***Tufts University*** provides 24,000 square feet of incubator space at its Grafton campus; these facilities currently house five start-up companies.
- The University of Massachusetts Boston is planning to develop a new incubator for environmental businesses as part of the ***Environmental Science and Technology Park***, now being developed on a 9.5-acre site adjacent to its campus.

Although Brandeis does not operate formal incubator space, it does provide space and support for early-stage faculty ventures. Archemix, for example — a company founded by a Brandeis faculty member and several Brandeis graduates that is developing the use of selected nucleic acids both as drugs and as tools for drug discovery — was "incubated" for five months at the ***Rosenstiel Center for Basic Medical Sciences.*** The company has already secured more than $51 million in venture financing.

Similarly, MIT does not itself provide incubator space. MIT officials have instead characterized the area around its campus as a "virtual incubator" — a place where entrepreneurs have ready access to all of the resources they need to launch a new business, including a highly skilled labor pool, professional service firms with extensive experience in working with start-ups, an a network of angel investors.

Boston University, unlike other universities in the region, is also directly involved in venture capital financing. Since 1975, ***BU's Community Technology Fund*** has actively sought out private equity investment opportunities in growing companies. While it does not focus exclusively on companies in the Boston area, the nature of venture investing is such that local companies are disproportionately represented in CTF's portfolio. As of 2001, CTF's portfolio was valued at $55 million.

While CTF's share of a typical deal is usually small — rarely more than 5 percent — many local companies that are in the process of raising capital find its participation attractive. CTF helps its portfolio companies with on-campus recruiting at BU, and helps them connect with faculty members who are doing relevant work. In some cases, BU faculty members are appointed to the companies' scientific advisory boards.

Faculty Involvement in New Business Development

Faculty at some of the research universities have long been active in the creation of new businesses. As of 1997, for example, there were 29 companies operating in the Boston area, employing more than 10,000 people, that counted MIT faculty members among their founders; and faculty at other universities have played a similar role. In some cases, faculty members are involved in starting companies that are bringing to market technologies licensed by their universities. In other cases — especially with consulting or research firms — ventures started by faculty members have no formal relationship to their universities. Table 6 cites several examples of firms, both large and small, started by university faculty members.

Table 6:
Selected Firms Started by University Faculty Members

Company	Headquarters Location	Year Founded	Faculty from	Area Employees
Genome Therapeutics	Waltham	1961	Brandeis	165
Archemix	Cambridge	2001	Brandeis	40
Biogen	Cambridge	1978	MIT, Harvard	1,250
Aspen Technology	Cambridge	1981	MIT	300
Cambridge Systematics	Cambridge	1986	MIT	100
Ascent Technologies	Cambridge	1986	MIT	23
Alkermes	Cambridge	1987	MIT	400
Machado and Silvetti	Boston	1974	Harvard	45
Monitor Group	Cambridge	1984	Harvard	450
Cambridge Energy Research Associates	Cambridge		Harvard	200
Boston Medical Technologies	Wakefield	1991	Harvard	18
NitroMed, Inc	Boston	1988	Boston U	38
Modular Genetics	Cambridge	2000	Boston U	9
Delphi Communication Systems, Inc.	Maynard	1993	Northeastern	25

MIT is renowned for an institutional culture that encourages faculty entrepreneurship. As other universities have developed formal technology transfer programs, their faculties as well are becoming more actively involved in the creation of new businesses. Several universities have begun to change personnel policies and practices to allow faculty members to pursue their entrepreneurial interests. In 1998, for example, Boston University allowed two professors of computer science to remain on the faculty with reduced teaching loads while they worked on getting a new venture, Commonwealth Network Technologies, off the ground.

As more faculty become involved in entrepreneurial activity, the odds increase that some of the ventures they launch will become the region's future growth companies.

University Graduates as Entrepreneurs

As noted in Part III, producing a steady stream of well-educated, highly-skilled graduates is probably the single most important way in which the eight research universities contribute to the continued development of the Boston area economy. Among the many ways in which university graduates contribute to region's economic dynamism, leadership in the creation and growth of new businesses is one of he most notable .

In 1997, BankBoston published a landmark study documenting the long-term economic impact of companies create by MIT graduates — not only in the Boston area but nationwide.[29] The phenomenon is not, of course, limited to graduates of MIT; graduates of all of the research universities can be found among the ranks of the region's entrepreneurs — both those who have already made a lasting mark on the local economy and those just starting out. For example:

- MIT graduates Alex d'Arbeloff and Nick DeWolf founded ***Teradyne*** in rented space above a hot dog stand in downtown Boston in 1960. The company has for forty years been a leader in the development of automated testing devices for semiconductors and other electronic components.
- In 1965, MIT graduates Ray Stata and Matthew Lorber founded ***Analog Devices,*** one of the Boston area's largest employers.
- Bernard Gordon, a former Tufts student and MIT graduate, founded ***Analogic Technologies*** in 1969; today the company, based in Peabody, is one of the region's largest medical technology firms.
- Richard Egan and Roger Marino, both graduates of Northeastern, founded ***EMC*** in 1979; the company is now a world leader in the development and manufacture of electronic data storage systems.
- In 1980 Carol Cone, a graduate of both Brandeis and Boston University, founded Boston-based ***Cone, Inc.***, one of the region's leading public relations firms.

[29] Bank Boston, *MIT: The Impact of Innovation*, March 1997.

Grooming the Next Generation of Entrepreneurs

During the past decade, the Boston area research universities have become more actively involved in encouraging — and in helping students prepare for — entrepreneurship. Perhaps the most notable of these efforts has been MIT's "$50K competition."

Each year, teams of aspiring entrepreneurs (each team must include at least one MIT student) prepare business plans for proposed new ventures. The program is not simply a contest, but an educational process as well. While they are developing and refining their plans, students take part in a year-long series of workshops and lectures on business planning, start-up financing, marketing and management, as well as an opportunity for "learning by doing." The plans are reviewed by a panel consisting of leading entrepreneurs and venture capitalists. They are winnowed down to a group of finalists; and after further review, the panel selects a winning team (which receives $30,000), and second and third-place finishers (who are awarded $10,000 each).

Since its inception, the $50K competition has become increasingly popular; in 2000, more than 200 business plans were submitted. The exposure that the competition provides, in terms of its ability to attract the interest of prospective investors, is of far greater value for many participants than the cash prize. Not only the winners, but the second- and third-place finishers and other finalists often draw the attention of angel investors and venture capital firms. Through 2001, the program had given birth to sixty companies — most of them in the Boston area — that had collectively attracted more than $175 million in venture capital, and that employed 1,800 people.

Entrepreneurial training at MIT is not limited to the $50K program. The two-year Biomedical Enterprise Program, a joint venture of the Harvard-MIT Division of Health Sciences and Technology and the Sloan School of Management, prepares graduate students "to transform scientific discoveries into…. commercially successful products and services."

Other Boston-area universities have also created programs aimed at developing student entrepreneurs. Northeastern has a "$60K" business plan competition, and at Tufts fledgling entrepreneurs compete each year for the Montle Prize. In 2000, Boston University established the Bronner E-Business Center and Hatchery, funded by BU alumnus Michael Bronner. Several times each year, the Center invites students at the School of Management to submit summary descriptions of their ideas for new ventures. A faculty panel reviews these summaries, and selects participants. The selected teams then go though an intensive six-to-eight week planning process. Teams that during this phase demonstrate the viability of their business ideas are then invited to participate in the "resource acquisition phase," a review of plans by a team of venture capitalists affiliated with the Center. Participating VC firms include leading firms such as Bessemer Venture Partners, Charles River Ventures and Highland Capital Partners.

If a team receives an offer of financing from one of these firms, it is then invited to join the Hatchery, which provides assistance, support and guidance in getting the new venture off the ground.

- George Colony, a Harvard graduate, started Cambridge-based ***Forrester Research*** in 1983; today it is one of the world's leading providers of information and strategic intelligence on the information technology sector.
- In 1985, Tom Stemberg, a graduate of both Harvard College and Harvard Business School, founded ***Staples***, now based in Framingham; fifteen years after opening its doors, the company reached $10 billion in sales.
- William Connell, a graduate of Boston College founded the ***Connell Limited Partnership*** in 1987; today Boston-based Connell LP, an industrial equipment manufacturing and metals recycling company, is one of the metropolitan area's largest privately-held businesses.
- In 1987 Boston College graduate Michael Gilligan was one of three founders of Boston-based ***Heritage Partners***, a private-equity investment firm that specializes in financing family-owned businesses.
- Mark Atkins, a University of Massachusetts Boston graduate, founded ***Vality Technology*** in 1990; the fast-growing software company was recently cited by *Boston Magazine* as one of the best places to work in Boston. (Vality was acquired in 2002 by Westborough-based Ascential Software.)
- In 1992 Dr. Lance Blumberg, a Brandeis graduate, co-founded ***Cambridge Heart***, a Bedford-based company that develops and markets non-invasive cardiac diagnostic systems.
- In 1992, Brandeis graduate David Housman founded Cambridge-based ***Variagenics***, a firm specializing in pharmacogenomics. Between 1992 and 2000, the firm attracted $55 million in venture capital, and by 2001 was one of the region's twenty-five largest biotech companies.
- Tom Ricciardelli, an MIT graduate, founded ***SelecTech, Inc.*** in 1994. Using an innovative injection molding process, Taunton-based SelecTech has greatly improved the cost-competitiveness of a variety of plastic products made from 100 percent recycled plastic.
- In 1995, Robert Davis, a graduate of Northeastern University, was among the founders of ***Lycos***, a pioneering Internet search engine. As CEO, he led the fast-growing firm through its merger with Madrid-based Terra Networks in 2000. Terra Lycos, which maintains its operating headquarters in Waltham, is today one of the world's leading Internet access, content and services companies.
- Tufts graduate Neil Birnberg launched ***Mercury Therapeutics, Inc.*** of Woburn in 1996 to develop new proteomic-based treatments for diabetes and cardiovascular disease.
- CEO John St. Amand, a Northeastern graduate, co-founded ***Telica, Inc.***, in 1998. The Marlborough-based firm has grown in four years from 7 employees to more than 200; attracted $120 million in venture capital, and emerged as a leading provider of switching software to the telecommunications industry.
- In 1998, Ling Chai — a leader of the 1989 student protests in China's Tienanmen Square, and more recently a graduate of Harvard Business School — founded ***Jenzabar, Inc.*** In just four years the Cambridge-based company has become a leading provider of software and intranet services to colleges and universities.

- In 1998, Boston University graduate Jeffrey Unger co-founded Boston-based ***GenuOne;*** the firm is already a world leader in the use of embedded "smart" technology to authenticate branded products, ID documents, and other objects.
- In 2000, MIT graduate Robin Chase founded ***ZipCar, Inc.*** The company's innovative car-sharing service could ultimately revolutionize the way people use cars in the nation's largest cities.
- In 2000, Boston College graduate Randy Seidl was one of three founders of ***Giant Loop***, a fast-growing provider of data movement solutions and services to global corporations; he is now its executive vice president. The Waltham-based company's CEO and general counsel are also Boston College alumni.
- Greg Altman started ***Tissue Regeneration Inc.*** in 2000 to develop methods for culturing knee ligaments for transplantation; the venture is based on work he began as a graduate student in bioengineering at Tufts.

The distinction drawn here between companies started by faculty members and those started by graduates is, of course, somewhat artificial. Some of the region's most notable start-ups are the products of collaboration between faculty members and their current or former students. For example:

- ***iRobot***, a leading developer of robots for industrial, military and domestic use, was co-founded in 1990 by MIT professor Rodney Brooks and two of his students, Colin Angle and Helen Greiner.
- MIT professor Thomas Leighton and the late Daniel Lewin — then still an MIT graduate student — founded ***Akamai Technologies Inc.*** in 1998. The company rapidly emerged as a world leader in Internet content routing.
- In 2000, MIT professor Leonard Guarente and MIT graduate Cynthia Kenyon started ***Elixir Pharmaceuticals***, a pioneer in the use of biotechnology to forestall the effects of aging.

Leadership in business development is not, however, limited to company founders. ***Graduates of the region's universities provide a deep and diverse pool of talent from which companies can draw as they seek both to generate and to manage growth. Among the firms listed in 2002 in the Boston Business Journal's ranking of the region's 100 fastest-growing publicly held companies, for example, 38 CEO's hold degrees from one or more of the eight universities.***

In this as in many other respects, it is the *concentration* of so many leading institutions in the Boston area that provides a particular source of competitive advantage. New and growing companies can draw on a talent pool that includes graduates of not just one or two major research universities, but eight (as well as many other colleges and universities). An informal survey of the leadership of some of the region's fastest-growing and most innovative companies offers numerous examples of entrepreneurial teams that include graduates of several local institutions.

- ***Speechworks International*** — a fast-growing developer of speech recognition systems — was founded in 1994 by Michael Phillips, who after graduating from Carnegie Mellon, had come to Cambridge to work at MIT's Computer Science Lab; Phillips remains with the

company as chief technology officer. In 1996, to help lead the company's growth, Speechworks hired a Harvard graduate, Stuart Patterson, as CEO. Other members of the firm's executive team include a senior vice president for operations who holds an engineering degree from MIT and a Boston University MBA, and a Harvard graduate as chief financial officer.

- At ***Mercury Computer Systems*** — a leader in digital image and signal processing — co-founder and CEO James Bertelli is a Northeastern graduate, the chief financial officer is an MIT graduate with a Harvard MBA, and the vice president for development and the chief information officer are graduates of Boston University.
- ***Lewtan Technologies***, founded in 1986, is a leading provider of software, data and analytics to companies participating in the market for securitized financial assets. Founder and CEO Stuart Lewtan, a Brandeis graduate; the company's CFO is a graduate of MIT, and the senior vice-president for marketing a graduate of UMass Boston.
- ***InfoLibria***, a provider of broadband content distribution systems, was founded in 1997 by Abdelsalam Heddaya, an associate professor of computer science at BU who holds a Ph.D. from Harvard; Heddaya today serves as InfoLibria's chief scientist. CEO Ian Yates has a Ph.D and an MBA from MIT; and chief financial officer Bob Cirrone is a graduate of UMass Boston with an MBA from Northeastern.
- In addition to Chairman Tom Stemberg, a Harvard graduate, ***Staples, Inc.'s*** executive team includes a chief operating officer who holds a Harvard MBA, a Northeastern graduate as CFO, and an MIT graduate as vice president for marketing.
- ***PhotonEx,*** a developer of "smart photonic systems" for public telecommunications networks, was founded in 1999 by CEO Kristin Rauschenbach and chief technology officer Katherine Hall, both graduates of MIT and former researchers at Lincoln Laboratory. The Maynard-based company's chief science officer is also an MIT graduate, its chief financial officer is a Boston College graduate, and its vice presidents for engineering and manufacturing are both Northeastern graduates. Between 1999 and 2002, PhotonEx attracted $178 million in venture capital investment.

Venture Capital's Human Capital

As noted in Part One of this report, it is important to view the research universities' role in new business development not in isolation, but as part of a broader regional network of firms and institutions that support the creation and growth of new businesses. In the Boston area, one of the most important components of this "infrastructure of innovation" has been a venture capital industry with a long history of investing in the growth of local companies.

The research universities' direct role in venture capital financing is limited. As noted above, Boston University is the only one of the eight that actively invests its own funds in local start-ups. Some invest passively, however, typically by placing a small percentage of their endowments funds with Boston-area venture capital firms. And some contribute indirectly to the financing of new ventures by taking stock from start-up companies in lieu of licensing fees or rents.

Probably more important than the universities' contributions to the venture industry's financial capital, however, is their contribution to its human capital. Since its birth in the 1940's, the region's venture capital community has looked to the local universities as their primary source of talent. In 2001, for example, 68 out of 135 senior managers at the Boston area's 25 largest venture capital funds were graduates of one or more of the eight research universities.

The presence of a large cadre of local graduates among the region's venture capital firms facilitates the translation of university research into new businesses. Local graduates' informal relationships can help them stay in touch with new developments on campus. Programs such as MIT's "$50K competition" (described above) help them identify new investment opportunities. And they can look to the universities for recruitment of employees and advisors for start-up companies.

Developing Commercial Real Estate

The growth of companies engaged in commercializing university research, or that were founded by university faculty or graduates, or that simply want part of the "knowledge communities" that have emerged in the Boston area, has generated a demand for commercial research and office space. Several research universities have been actively involved in developing the space needed to support the continued growth of the region's knowledge industries.

MIT

MIT has been involved in off-campus commercial real estate development since the 1960's. At the request of the City of Cambridge, MIT worked with a private partner to redevelop the site of an abandoned soap factory near its campus. The site became Technology Square, the initial focal point for the growth of the city's technology sector. After selling its

share of the project to the developer in 1973, MIT reacquired Tech Square in 2001, at a cost of $279 million, and proceeded to complete construction of four new buildings. The Tech Square complex now consists of seven buildings with a total of more than 1 million square feet of commercial space.

In 1983, MIT entered into an agreement with Forest City Enterprises for development of University Park, a 27-acre, 2.3 million square-foot mixed-use project in what had been a declining industrial area. University Park today includes commercial office, research and retail space, a mix of market-rate and affordable housing, a 210-room hotel, a day care center, a 925-car garage and the University Park Commons.

In the early 1990's, the Institute also redeveloped a 220,000 square-foot former Ford assembly plant at 640 Memorial Drive, to provide space for the city's fast-growing biotech industry. Since then, MIT has bought, built or renovated several other commercial buildings, and has several others under construction. It now owns approximately 3.8 million square feet of commercial space in Cambridge.

MIT invests its endowment and pension funds only in projects that make sense economically, and on which it can earn an adequate return; it generally does not provide subsidized space either for MIT-related companies or other tenants. Nevertheless, its involvement in commercial development is in many respects a natural extension of its commitment to translating academic research and innovation into new products and new businesses. As one MIT administrator recently observed:

> *Somebody comes up with an idea; that's the intellectual capital. To grow it, you need internal financial capital, external financial capital and physical capital — space. Whatever community can come up with all three is where the idea will land.*

Boston University

Because their work remains closely tied to advances in basic science, and because of the long lead times involved in bringing products to market, biotechnology companies seem especially inclined to stay close to centers of academic and clinical research. Like MIT, Boston University has sought to accommodate the growing demand for space through its sponsorship of BioSquare, a mixed academic-commercial development adjacent to Boston University Medical Center.

A master plan for BioSquare — located on a fourteen-acre site assembled through purchases from the city and private owners — was approved by the city in 1990. Permits were issued for the development of 1.2 million square feet of space; in a second phase, the plan envisions development of an additional 1.3 million. The first building at the site, BioSquare I, was completed in 1993. It houses BU academic research facilities, some of which are available for use by private firms. BioSquare II was completed in 1997; BU occupies 60 percent of the building, with the remaining 40 percent being rented to five private tenants. BU has also developed a 1,000-car parking garage at the site. BU is currently negotiating terms for the development of BioSquare III; it expects that two-thirds of this 160,000 square foot building will be occupied by commercial tenants.

A Research Park Takes Root in Grafton

The newest university-sponsored real estate development project in the Boston area is Tufts University's Tufts Science Park, a 106-acre site located on the campus of the University's School of Veterinary Medicine in Grafton, six miles west of I-495. The approved master plan for the Park calls for the development of 702,000 square feet of space; allowable uses include research and development, pilot manufacturing and other activities relating to the biotechnology, biomedical and pharmaceutical industries.

The Tufts Biotechnology Corporation (a for-profit corporation controlled by the University) will be responsible for the project. The Science Park will be developed in two roughly equal phases. Construction of basic infrastructure for Phase I got under way during the summer of 2002.

Helping to Create Tomorrow's Growth Companies

Just as they helped the Boston metropolitan area pull out of a severe recession a decade ago, the research universities today are helping give birth to many of the dynamic young companies that will drive the next round of regional growth. ***Of the fifty early-stage, Boston-area start-ups that attracted the most outside investment between October 2001 and September 2002, 25 — including seven of the top ten — had some connection to one or more of the eight universities.*** That is, they were engaged in the commercialization of technologies first developed at one of the universities; were founded by a faculty member or graduate; were born in a university incubator, or had a CEO who had graduated from one of the universities. Together, these 25 companies attracted more than $225 million in early-stage investment in 2001-02. (Table 7 lists the ten university-related early-stage start-ups that attracted the most investment.)

Table 7
Boston-Area Start-Ups with University Connections

Ranked by Early-Stage Investment / October 2001 to September 2002

Rank in BBJ Top 50	Company	Headquarters	Yr. Fd.	Total $ Raised	University Connection
1	Gold K	Waltham	1999	$36,800,000	MIT
3	Seranoa Networks	Concord	2000	$18,300,000	Tufts
4	Alnylam Pharmaceuticals	Cambridge	2002	$17,000,000	MIT
5	GenPath Pharmaceuticals	Cambridge	1996	$15,500,000	Harvard
6	OmniGuide Communications	Cambridge	2000	$14,500,000	MIT
7	Imprivata Inc.	Lexington	2000	$13,500,000	Harvard
9	Relicore Inc.	Burlington	2000	$11,000,000	MIT, Harvard
14	Smart Time	Framingham	1986	$10,000,000	Northeastern
15	DataPower Technology	Cambridge	1999	$9,500,000	MIT
17	A123 Systems	Cambridge	2001	$8,300,000	MIT

The ideas, assistance, talent, connections and investments that the universities provide to young companies such as these are, in effect, the basic ingredients for continued economic growth.

Part Three:

Research Universities:
A Major Regional Industry

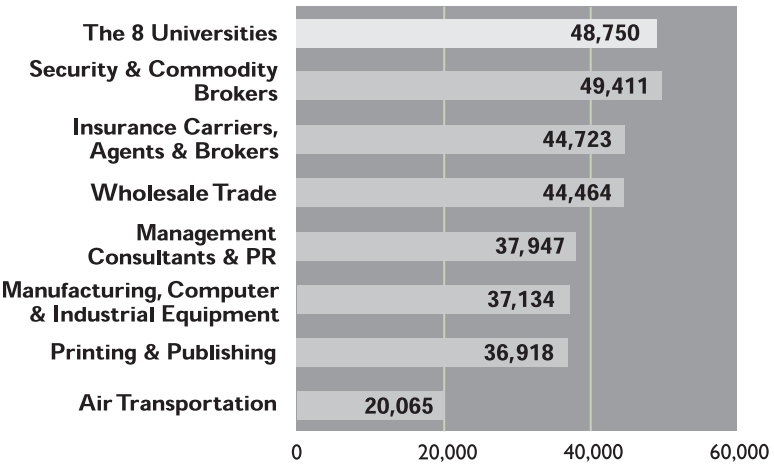
VI. Employment at the Research Universities

In addition to being a key element of the region's intellectual and entrepreneurial infrastructure, the universities also constitute a significant industry in themselves. In 2000, these eight institutions had revenues totaling $5.8 billion. They are among the region's largest employers — they are major buyers of goods and services from businesses throughout the region — and they are perennially among the region's leading sponsors of construction projects.

A Major Regional Employer

In 2000, the eight Boston-area research universities together employed 48,750 people — 36,925 full-time and 11,825 part-time.[30] While they employ fewer people in the Boston area than major local service industries such as retailing and hospitals, the research universities (as Figure 4 shows) collectively employ more people than a number of other leading "export" industries in the Boston area, including banking, insurance, management consulting and computer manufacturing. Together, the universities accounted for about 2.2 percent of all payroll employment in the five-county area, and about 2.4 percent of all wage and salary payments.

Figure 4:
Employment at the Universities Compared with Leading Industries



The research universities are notable not only for the number of people they employ, but for their stability. They are much less vulnerable than some of the Boston area's other leading growth industries, such as financial services and information technology, to cyclical swings in the regional economy. ***Between October 2000 and October 2002 — a period during which the***

[30] These totals exclude part-time student employees, as well as short-term temporary or "casual" employees. Because different institutions account differently for these groups, their precise numbers are difficult to quantify. We estimate that at any given time during the academic year, approximately 20,000 to 25,000 students are employed in part-time jobs at the eight universities. In dollar terms, however, students and casual employees (for example, game- day workers at athletic events) account for only a small percentage of the universities' collective payroll.

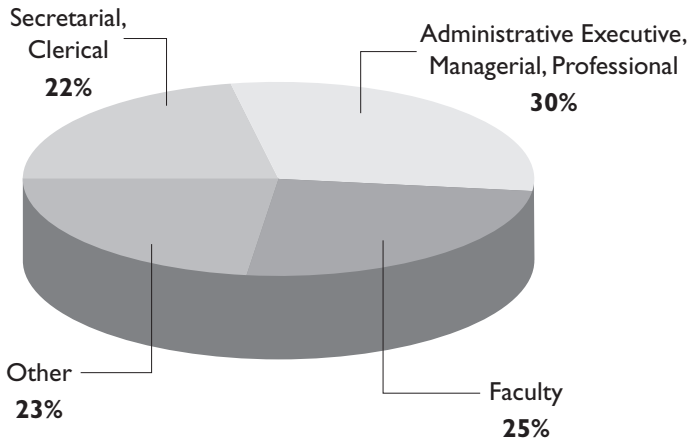
Boston area saw total employment decline by 58,000, a loss of about 2.8 percent — the eight universities collectively added approximately 2,000 jobs, an increase of about 4 percent. This brought total employment in this sector to approximately 50,750.

The significance of the research universities as employers is further evident when we compare them to other major non-governmental employers in the Commonwealth. Four of the universities are among the twenty-five largest private employers, as reported by the *Boston Business Journal*. Collectively, the eight employ roughly as many people as Fidelity, State Street, FleetBoston, Raytheon and Gillette combined.[31]

The combined payroll of the eight universities in 2000 totaled $2.5 billion, of which approximately $2.2 billion was paid to residents of the Boston metropolitan area. The salaries and wages that university employees take home are spent in communities throughout the Boston area on rent, home mortgage payments, groceries, child care, entertainment, and a wide variety of other locally purchased goods and services.

In addition to the net earnings their employees take home, ***in 2000 the universities collectively transmitted to the Commonwealth of Massachusetts approximately $115 million in income taxes paid by their employees.*** Employees also pay real property taxes in their home communities, as well as sales taxes on purchases of goods and services.

Figure 5:
Occupational categories



The universities are notable not only for the number of people they employ, but also for the variety of jobs they offer. The eight institutions in 2000 employed more than 12,000 faculty members; but they also employed thousands of research technicians, administrative and clerical staff, and others, including thousands of workers in blue-collar jobs in areas such as maintenance, security and food services.

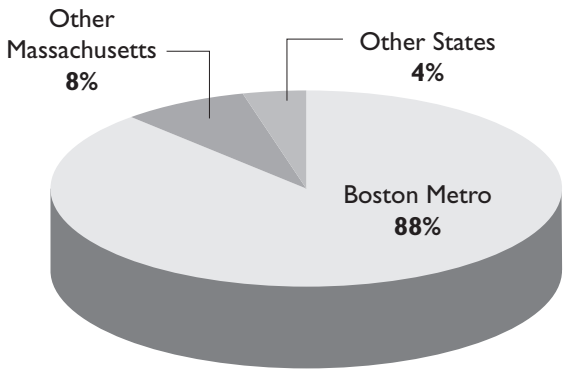
Not surprisingly, as figure 6 shows, the overwhelming majority of the universities' 48,750 employees in 2000 were residents of the Boston metropolitan area.

[31] *Boston Business Journal*, Dec. 27, 2002-January 3, 2003, p. 19.

The eight universities all employ significant numbers of residents of the communities in which they are located. In 2000:

- Boston College employed 1,248 residents of Boston and Newton.
- Boston University employed 2,179 Boston residents.
- Brandeis employed 482 residents of Waltham.
- Harvard employed 2,806 Boston residents, and 3,699 residents of Cambridge.
- MIT employed 1,797 Cambridge residents.
- Northeastern employed 1,302 Boston residents.
- Tufts employed 1,061 residents of Somerville, Medford and Boston.
- UMass Boston employed 1,001 Boston residents.

Figure 6:
Location of Residences of Employees



The Quality of Jobs: Wages and Training Opportunities

The universities are notable not only for the number of people they employ, but also for the quality of the jobs they provide. The quality of employment has many dimensions; here we focus on just two — wages, and opportunities for education and training.

The range of salaries and wages the universities offer varies from institution to institution and across occupational categories, but they are generally competitive. Average faculty salaries at several Boston-area universities are among the highest in the U.S.; these salaries help bring to the Boston area some of the world's leading teachers and researchers. At the same time, the universities pay locally-competitive wages in a wide range of non-professional jobs — clerical workers, maintenance workers, and other support staff. For all employees, earnings at the eight universities in 2000 averaged approximately $51,000 — about 7 percent higher than the average for all wage and salary employment in the region.

The quality of employment is not determined solely by salaries and wages, however. It depends as well on the opportunities to acquire new skills and increase earning power that a job provides. From this perspective, the quality of research university jobs is particularly noteworthy; they offer their employees extensive opportunities for education and training.

A Bridge for Less-Skilled Workers

Opportunities for education and training can make university jobs particularly attractive for less-skilled workers. Harvard's "Bridge to Learning and Literacy" program, for example, offers the University's service workers free classes in English as a second language, reading, writing, listening and speaking skills, basic computer skills and GED preparation. Harvard employees can take classes for up to four hours per week of paid released time; and in the fall of 2001, eligibility for the program was expanded to include employees of on-site service contractors — primarily janitorial and food service workers.

Since its founding as a pilot project in 1999, the Bridge program has been highly popular among Harvard's less-skilled service workers; enrollment has grown from 38 in the fall of 1999 to more than 400 in the spring of 2002. The program helps workers develop skills that will help them succeed in their current jobs. Perhaps even more important, it helps them acquire the skills they will need to take advantage of other educational opportunities that Harvard offers to its employees — taking courses at the Harvard Extension School, for example, or (through the Tuition Assistance Program) at other local institutions.

In December 2001, the Harvard Committee on Employment and Contracting Policies (a group of faculty, administrators, union and employee representatives and students created in 2001 to address a range of issues affecting the University's lower-wage workers) recommended continued expansion of the program.

- Boston University remits 100 percent of tuition charges for courses that employees take at the University, for up to four credit hours per semester, and remits 90 percent of charges for an additional four credit hours per semester. BU's human resources department also offers training in areas such as business writing, procurement and customer service.
- At Brandeis, full-time non-professional employees can enroll in one course per semester, tuition-free; and their children are eligible for tuition-remission benefits equal to 75 percent of four years' full tuition.
- Harvard's Tuition Assistance Program enables employees to take courses at Harvard for as little as $40 per course. The program also fully or partially reimburses employees for the cost of job-related courses taken at other institutions.
- MIT's Education Assistance program provides up to $5,250 in tuition assistance for job-related courses that MIT employees take at other institutions.

- Northeastern provides employees with tuition remission for courses they take at the University, for up to nine hours of courses per quarter.
- At Tufts, the University's Computing and Communications Services offers training in a wide array of computer applications to all University employees. Employees are also eligible to enroll in regular courses at Tufts, and receive tuition remission benefits for their children.

Providing Opportunity

As the preceding data show, the research universities are a source of employment opportunity for more than 50,000 people. They employ more than just professors and Ph.D. researchers; for every faculty member, the universities employ three other professional, administrative, clerical or support workers, generally in high-quality jobs. The universities, moreover, offer clerical and support workers opportunities for education and skill-building that are available in few other industries — a benefit that makes these jobs especially valuable in an economy in which opportunities for learning are as essential as opportunities for earning.

The research universities' investments in their employees' skills, moreover, do not just benefit the workers themselves, or the universities as employers. Especially to the extent that employees who are educated at the universities sometimes move on to other jobs in the Boston area, their training represents a substantial investment in the region's stock of human capital.

VII. Purchasing and Construction

In addition to contributing to the health of the regional economy through the employment of Boston metropolitan area residents, the eight universities have a significant impact through the purchase of goods and services from local companies; and by their investments in new facilities and in the renovation and modernization of existing ones.

Purchases of Goods and Services

In fiscal year 2000, we estimate that the eight institutions bought more than $1.3 billion in goods and services from businesses located in the Boston metropolitan area. The range of businesses from which they buy is as broad as the regional economy itself. At BU, for example, local industries with which the University spent at least $5 million within the region include computers and other electronic equipment, utility services, real estate, insurance, business services and health care.

As with employment, the impact of university purchasing can be especially significant at the local level. In 2000:

- Harvard University bought $275 million in goods and services from Boston firms, and $56 million from Cambridge companies.
- Boston University spent $126 million on goods and services supplied by Boston companies.
- Under its "Cambridge First" policy, Massachusetts Institute of Technology spent nearly $37 million on purchases from businesses located in Cambridge.
- Boston College spent approximately $34 million on purchases of goods and services in Boston and Newton.

Many of the services that universities buy locally relate to the management of their facilities. Major local contractors of Harvard, for example, include building maintenance and food service contractors.

Large companies are not the only beneficiaries of local purchasing by the research universities. Smaller local companies from which Tufts University purchased goods and services in 2000 included catering companies, office temp services, florists, office supply and office furniture companies, print and copy shops, and cab companies.

Several universities have made special efforts to reach out to and do business with local minority and women-owned companies. As a result of such efforts, for example, Northeastern in 2000 purchased more than $4.4 million in goods and services from minority and woman-owned vendors, and Boston University, more than $4.3 million.

University Construction

The eight Boston-area research universities are consistently among the region's leading sponsors of construction projects. ***In 2000, construction spending by the eight institutions totaled more than $550 million.***

University construction contributes to the strength of the regional economy in several ways. It is a major source of business for the region's construction contractors, and a major source of employment for Boston-area construction workers. ***We estimate that in 2000, university building projects generated approximately 3,300 full-time-equivalent construction jobs.***

Supporting a growing research and teaching enterprise

Even more important, construction of new facilities and the renovation of older ones is an investment in the region's intellectual infrastructure. This investment is essential to the continued growth of the universities' research enterprise, and to the development of new educational programs. Projects recently completed, currently under way or planned include:

- The new ***Ray and Maria Stata Center for Computer, Information and Intelligence Sciences*** at MIT — a 430,000 square-foot complex that will include new classrooms and labs, an auditorium, and other facilities. The Stata Center complex includes the William Gates Building, housing the Laboratory for Computer Science, and the Alexander Dryfoos Building, housing the Artificial Intelligence Laboratory, the Laboratory for Information Decision Systems and the Department of Linguistics an Philosophy. The complex also includes an underground parking garage.
- A new 525,000 square-foot ***Harvard Medical School research building*** (described below).
- A new ***Center for Government and International Studies***, a 260,000 square-foot complex that will provide classroom, library, conference, computer and office space for Harvard's Government Department, and for several research institutes.
- A new 94,000 square-foot building at ***60 Oxford Street*** in Cambridge, which will house a new computer lab, as well as faculty office space, for Harvard's Division of Engineering and Applied Science.
- At Northeastern, the ***Behrakis Health Sciences Complex,*** completed in 2002, which now houses the Bouve College of Health Sciences.
- Northeastern's new ***Buildings G and H,*** now under construction — a 299,000 square-foot complex that will house the College of Computer Science, along with additional classroom space and student apartments.
- Approximately 190,000 square feet of ***research space for the life sciences and computer science*** that Boston University plans to develop at its Charles River campus.
- At Boston College, an $80 million renovation and expansion of ***Higgins Hall***, a center for research and teaching in physics and biology.

- ***The Jaharis Family Center for Biomedical and Nutrition Science***, a new 175,000 square-foot on Tufts University's Boston campus, which houses the Friedman School of Nutrition Science and Policy, as well as new space for collaborative biomedical and nutrition research.
- A new 35,000 square-foot building for the psychology department on Tufts' Medford campus.
- At Brandeis, a new, 20,000 square-foot ***Living and Learning Center***, providing classroom, office and student support services for the Graduate School International Economics and Finance.

Accommodating a Growing Medical Research Enterprise

A new facility at the Harvard Medical School's Longwood campus, called simply the New Research Building, illustrates the importance of new construction in supporting emerging areas of — and evolving approaches to — university research.

The 525,000 square-foot New Research Building, on which construction began in February 2001, will be immediately adjacent to the existing Harvard Institutes of Medicine building, and to a new research complex being developed by Merck & Co. The new building will accommodate expansion of research activity in areas such as neurobiology, molecular genetics, applied genomics and proteomics. Recognizing the growing importance of collaboration between laboratory and clinical researchers, the facility was planned and designed to accommodate cooperative projects involving both Harvard Medical School and its affiliated institutions.

The new building, which will include both lab and conference space, will cost a total of $250 million. Construction is scheduled for completion in late 2003.

Creating a more attractive environment

In an age when the ability to attract talent is vital to regional competitiveness, universities need to create and maintain an environment that helps them attract talented students. This requires investment not only in classroom and research facilities, but in student housing, space for extracurricular and recreational activity, and other facilities that help to create an attractive community. Housing projects recently completed, currently under way or planned include:

- At Boston College, a multi-phase student housing program, begun in 2000, that upon completion in 2004 will have increased by 800 the number of students that are housed on campus. When the program is completed, 85 percent of all undergraduates will be housed on campus.
- A 200-bed undergraduate residence hall on Brandeis University's Waltham campus.
- A 240-unit apartment complex for Harvard graduate students at 1 Weston Avenue in Allston.
- MIT's Simmons Hall, a new residence housing 350 undergraduates, graduate assistants, and visiting scholars.

- A 346,000 square-foot dormitory complex at 70 Pacific Street in Cambridge, housing more than 700 MIT students.
- At Northeastern, a multi-year student housing program that has since 1999 increased the capacity of the University's residence halls by 2,500 beds. Northeastern's most recent project, Davenport Commons (described below), combines residence halls for 600 students with 75 units of housing for community residents.
- A Tufts, planning is under way for a new residence hall for 150 students that will incorporate the latest "green building" standards. Development of additional housing for graduate students is also being explored.

Meeting the University's Needs — and the Community's

Northeastern University's Davenport Commons development exemplifies how major capital projects designed to meet university needs can benefit the community as well. It provides living space for approximately 600 students in two residence halls. Davenport Commons also includes 2,000 square feet of ground floor retail space, and 75 condominium apartments and townhouse units that were made available to neighborhood residents at prices aimed at making them affordable to families at different income levels. More than 700 local families submitted applications to purchase these units.

The $51 million project, located on Douglass Park Avenue in Boston, is the product of extensive University consultation with community organizations and local officials. It also involved active collaboration with several private, non-profit and public-sector organizations, including Madison Park Development Corporation, the Massachusetts Housing Finance Agency and Lehman Brothers.

In what could prove to be among the most significant changes in the region's student housing patterns, the University of Massachusetts Boston in 2002 began planning the development of housing for as many as 2,000 students. Despite its growth over the past several decades, Boston has been the only UMass campus that does not provide housing for its students. UMass Boston is now moving ahead with the first phase of its program — the construction of on-campus residences for 700 students. Construction is scheduled to begin in 2003, and will be completed by 2004.

Projects that will expand and enhance athletic and recreational space, and space for other student activities, include:

- ***Brandeis's Shapiro Campus Center,*** a 63,000 square foot building that will include space for student organizations and activities, and a 250-seat theater.
- ***The Spangler Center,*** a 121,000 square-foot student center at the Harvard Business School's Allston campus, completed in 2001.
- ***Tufts University's Dowling Hall,*** which combines new, consolidated space for student services with a 500-car garage.

- ***Tufts University's Gantcher Center,*** opened in 2000, which combines athletic facilities and space for campus convocations in a 66,000 square-foot facility.
- ***MIT's Zesiger Sports and Fitness Center*** — a new 125,000 square-foot athletic center that includes an Olympic-size pool, basketball and squash courts and other facilities.
- ***The University of Massachusetts Boston's new 331,000 square-foot Campus Center*** — including space for student services and activities, dining facilities and a conference center — which will provide a dramatic new "front door" for the Columbia Point campus.

A New Student Village

One of the most ambitious efforts to create an environment needed to attract and retain talented students, faculty and researchers in the Boston area is Boston University's John Hancock Student Village project. The Student Village, located on a ten-acre site on Commonwealth Avenue once occupied by a National Guard armory, will include four apartment-style residences that will accommodate up to 2,300 students, as well as several athletic and recreational facilities:

- An 88,000 square-foot Track and Tennis Center;
- A 282,000 square-foot Fitness and Recreation Center;
- A 280,000 square-foot, 7,200 seat Sports and Entertainment Arena; and
- A 282,000 square-foot underground parking garage,

The first of the planned residential buildings, with room for 817 students, opened in the fall of 2000; and the Track and Tennis Center opened in 2002. Most of the remaining construction will be completed within the next five years.

More than bricks and mortar

Even in the Internet age, teaching and research are still — and will remain — heavily dependent on sustained face-to-face interaction, and on a sense of community. To satisfy these requirements, research universities need space. And as their mission grows and evolves, so do their space needs.

University investments in academic, residential and ancillary facilities thus represent far more than grist for the region's construction industry, or the continued bulking up of institutions that might sometimes appear, from the perspective of their neighbors, to be too big already. They are long-term investments in the universities' ability to perform the functions on which the region's economic vitality increasingly depends — attracting and developing talent, creating new knowledge and supporting business development.

Measuring the Multiplier

The billions of dollars in revenues that the eight universities bring in each year from around the nation and the world and spend within the Boston area have an impact on jobs and economic activity that goes beyond their own direct employment and purchases of goods and services. The money that their employees spend within the region on housing, groceries, day care and other routine needs has a further impact on the regional economy. The Boston-area companies from which the universities buy goods and services similarly pay their own employees, and buy goods and services from their own employees — all of whom in turn spend part of their earnings within the region.

Such "multiplier effects" can be difficult to measure. Using an input-output model, however, we can estimate the overall impact of the money the universities spend as it ripples through the region's economy. An input-output model is essentially a matrix, based on actual historical data, that defines how any given amount of spending by a firm in one particular industry flows through to other industries and households in the same geographic area; and how spending by those industries and households in turn affects other industries and households, and so on through several rounds of spending.

To measure the multiplier effect of university spending within the region, we used a version of the IMPLAN input-output model — a widely-used model originally developed by the U.S. Department of Agriculture — that is specifically tailored to the five-county Boston area. The model allows us to trace three types of impacts:

- ***The direct effect*** — the increase in economic activity at the local businesses from which the eight universities and their employees buy goods and services.
- ***The indirect effect*** — the increase in economic activity that occurs when the universities' Boston-area suppliers use some of the money they are paid by the universities to buy goods and services from other businesses in the Boston area; these businesses in turn spend some of their income on locally-produced goods and services, and so on.
- ***The induced effect*** — the economic activity that results from local household spending by employees of all of the companies directly or indirectly affected by university spending.

Taking these three types of effects into account, we estimate that ***the $3.5 billion the universities spent within the region in 2000 on payroll, purchasing and contracting generated an additional $3.9 billion in economic output, including $1.6 billion in wages, and more than 37,000 full-time-equivalent jobs.***

VIII. The Impact of Student and Visitor Spending

Undergraduate and graduate students at the eight research universities represent an important source of well-educated, highly-skilled workers for Boston-area companies, and an ongoing source of entrepreneurial vitality. But as students, they also contribute to the region's economy in a more immediate way, through the money they spend while living and studying in the Boston area. Similarly, people who visit the universities for a variety of purposes also spend money in the Boston area; and they too contribute to the health of its economy.

We estimate that students at and visitors to the eight research universities spent at least $1.1 billion in the Boston metropolitan area in 2000.

The Impact of Student Spending

Using data provided by each institution, we can estimate how much students spend on housing, food, and other needs. Spending levels vary according to students' living arrangements. They are typically highest for graduate and professional students living in off-campus private housing. (About two-thirds of all MIT graduate students, for example, and three-quarters of all BU graduate students, live in private housing.) University estimates of graduate student living costs are typically on the order of $16,000 per year. Table 8 presents estimates of graduate student living costs provided by several institutions.

Table 8:
Estimated annual living costs for single graduate students, selected universities.

Boston University	$16,590
Harvard	16,600
Northeastern	15,600

To avoid double counting, we do not count here room and board paid by students living on campus, or rents paid by those living in university-owned off-campus apartments; these payments are already counted in our data on university revenues and expenditures.

It is not just those living off-campus, of course, who spend money locally. Students living in university residence halls or apartments spend money on food, entertainment, local transportation and miscellaneous personal needs. Boston University, for example, estimates that miscellaneous personal spending by students living on campus average $1,350 during the academic year; Northeastern's year-round estimate is $2,550.

On the basis of this data, we estimate that in 2000, students at the eight universities spent more than $850 million on housing, food, clothing, supplies, entertainment, personal services and other routine needs.

Spending by Visitors

People who visit the eight universities — for conferences and other academic gatherings, to visit friends or relatives, or to do business with institutions — also contribute to the local economy. A 1999 study of Harvard University's economic impact, for example, estimated that visitors to Harvard spent approximately $72 million in the Boston area in 1997-98.

Few universities routinely and consistently collect information about visitor traffic. Enough data is available, however, to allow us to illustrate the magnitude of this traffic, and its economic impact.

- Boston College reports that more than 20,000 guests attended commencement ceremonies at BC in 2001.
- Brandeis University estimates that in 2000, more than 33,000 out-of-town visitors came to its Waltham campus for commencement, conferences, athletic competition and other events.
- Tufts University estimates that nearly 70,000 visitors came to its campus for major events and campus visits.
- Northeastern reports that its 2001 commencement ceremonies drew 16,000 guests; and that more than 20,000 prospective students visited its campus during 2000-01.
- MIT's Office of Corporate Relations estimates that in 2001 approximately 4,100 corporate representatives visited Cambridge to participate in conferences and other events designed specifically for a corporate audience. The Office reports that "virtually 100 percent" of these visitors stay in area hotels during their visits to Cambridge.

It is not just these formal campus events that draw out-of-town visitors to the universities. Students' friends and family members also travel to the Boston area for personal visits.

- Boston University estimates that in 2001 students' visitors spent more than $29 million in the Boston area.
- Boston College similarly estimates that parents and friends of its students spent $29 million off- campus — for hotel rooms, dining, entertainment and other purposes — during their visits to Boston College. More than 80 percent of this total was spent in the immediate vicinity of the campus.

In addition to these occasional visitors, the continuing professional education programs described in Part III draw tens of thousands of visitors to the Boston area each year. The duration of these programs lasts from a single day to several months.

Executive education programs offered by the universities' business schools are an especially significant source of visitor traffic. MIT, for example, reports that in 2000-01 enrollment in its executive education program totaled more than 104,000 "participant-days" (total enrollment in each program, multiplied by its duration); and that 90 percent of all participants came from outside the Boston metropolitan area.

The limited nature of the available data on visitors to the universities precludes any precise measurement of the local impact of visitor spending. Based on studies completed at several schools, ***we can nevertheless estimate that total spending in the Boston area by all types of visitors to the eight universities totaled at least $250 million in 2000.***

Much More Than Fun and Games

For thousands of students at the eight universities, participating in intercollegiate sports is an important part of their educational experience. Athletic events also help create the kind of interesting, exciting environment that helps attract talented students. Intercollegiate sports also contribute more directly to the local economy, however, by attracting tens of thousands of visitors each year to the Boston area. Boston College's athletic department, for example, estimates that regular-season home games in four major sports — football, men's ice hockey, and men's and women's basketball — attract nearly 21,000 out-of-town visitors to the Boston area annually. If these visitors spend an average of $100 each (over and above what they spend on campus for tickets, refreshments and other purposes), then this group would generate approximately $2.1 million annually in local spending.

Tournament-style events can generate even more spending within a short period of time. In 2003 Boston College is hosting the first and second rounds of the NCAA men' basketball tournament. The College expects that these games will attract a total of 9,000 visitors to the area. Because many of these visitors will stay in the area for several days, they will on the average spend significantly more money. If we assume an average of $400 in local spending per visitor, than we can estimate that this one event will generate approximately $3.6 million in spending within the Boston area.

Part Four:

Helping Communities Respond to the Demands of a Changing Economy

IX. Preparing the Region's Residents for Work in the Knowledge-based Economy

The growth of the Boston metropolitan area's idea-based economy has created unparalleled opportunities for area residents and businesses. But it also poses real challenges for communities throughout the region.

To succeed in the region's idea-based economy, Boston-area residents must be ready to meet employers' demands for higher levels of skills and education. As noted in Part III, the research universities — along with other colleges and universities in the Boston area — play a major role in helping the region's residents meet these demands.

But to take advantage of the opportunities for higher learning that these institutions offer, the region's residents need a solid grounding in basic skills. Success in today's economy thus depends more than ever on the quality of elementary, secondary and adult basic education. The eight research universities are helping communities throughout the region meet this prerequisite for success in the new economy, both by helping to strengthen local school systems and through programs aimed at directly assisting individual students.

Helping Communities Build Stronger Schools

The universities' most basic contribution to K-12 education comes through the education and training of teachers. Boston College, Boston University, Harvard, Northeastern, Tufts and the University of Massachusetts Boston all offer programs in education at either the undergraduate or graduate levels.

Universities that do not operate schools of education also contribute to the preparation of teachers for the region's elementary and secondary schools. In 2001 for example, 148 Brandeis graduates were teaching in schools throughout the Boston area.

Training Boston's Teachers for 150 Years

The oldest and largest teacher training program in the Boston metropolitan area is that offered by the University of Massachusetts Boston. Founded in 1852 as Boston Girls' High School, its primary purpose was to prepare young women to work as teachers in the city's emerging public school system. Early in this century, the school evolved into the Teachers College of the City of Boston, which later grew into Boston State College — and in the 1960's, UMass Boston.

Today UMass Boston's Graduate College of Education offers a four-semester sequence of courses leading to certification of undergraduates as beginning teachers, and enrolls more than 1,000 teachers each year in fives masters degree and two doctoral programs. The College also offers a wide array of in-service training programs.

The universities' involvement in improving elementary and secondary education goes well beyond formal degree programs, however. They provide a wide range of other services to school systems, teachers and students in Boston-area schools. Perhaps the most dramatic example (described in detail below) is the unique partnership developed more than a decade ago between Boston University and the City of Chelsea, under which BU has taken on responsibility for both day-to-day management and long-term improvement of the city's public schools.

The universities also provide a wide variety of continuing professional development opportunities for teachers and other school personnel. Here we will highlight just a few examples:

- At the University of Masschusetts Boston, the ***Field Center for Teaching and Learning*** provides programs for both beginning and veteran teachers, aimed at developing both content knowledge and classroom skills.
- UMass Boston recently announced a new ***"Pipeline" program***, aimed at recruiting, training and helping to retain teachers for the Boston, Cambridge and Somerville school systems. The initiative includes an effort to encourage outstanding high school students from the three cities to pursue teaching as a career, taking advantage of the state's "Tomorrow's Teachers" scholarship program. It also offers scholarships for master's degree candidates at UMass Boston who commit to teaching for at least three years in city schools; and provides ongoing support for these teachers through seminars, mentoring and networking opportunities.
- Boston College is the lead institution among seven colleges and universities participating in the ***Massachusetts Coalition for Teacher Quality and Student Achievement*** — a collaborative effort aimed at enhancing the quality of teacher training in Boston and several other cities.
- Through Boston College's ***THEMES*** project — Technology Helping Educators Master Essential PrincipleS— practicum supervisors and student teachers work with teachers in Boston public schools to integrate the use of technology more effectively into the classroom.
- Boston College's ***Boston Collaborative Fellows*** program each year supports a team of faculty members and students working with administrators and teachers in Allston and Brighton schools to improve teaching and learning, and to improve the quality of in-service training.
- MIT's ***Science and Engineering Program for Teachers*** is an intensive, one-week program that is offered each year at the end of June. The program is aimed at providing elementary and secondary school teachers with an understanding of the latest advances in mathematics, physics, chemistry and the life sciences. Teachers who have participated in the program have created their own organization, New England Science Teachers, which is based at MIT. NEST works to promote improvements in science education, and greater public appreciation of the importance of science, in communities throughout New England.

Transforming a Troubled School System: The Boston University/Chelsea Partnership

Perhaps the most dramatic example of university involvement in improving the quality of public education is Boston University's partnership with the Chelsea Public Schools. The City of Chelsea, a small city with a population of approximately 29,000, has long been one of the poorest communities in the Boston metropolitan area. In the 1980's, as the city's economy deteriorated and its finances fell into disarray, its school system came to be seen as the most troubled in the region. In 1989, the Chelsea School Committee invited Boston University to take on the task of transforming the city's schools.

The result was a ten-year contract between the City and the University that made BU the first private university in the U.S. to take direct responsibility for the day-to-day management of a local school system. The contract spelled out seventeen areas in which BU was committed to improving the school system's performance, including curriculum development, teacher training, creating a community school program, improving physical facilities and financial management, raising attendance and graduation rates, and raising standardized test scores. Since 1989, the Boston University/ Chelsea Partnership has made significant progress in all of these areas. For example:

- BU has created an early childhood education program that serves 400 three- and four-year-olds.
- The University has developed a comprehensive professional development program that includes after-school classes, summer courses, and payment of tuition for training at local universities.
- With financial support from the Commonwealth, the city's obsolete school buildings have been replaced; seven new schools were built, and one was completely renovated.
- Between 1997 and 2000, the average national rank of Chelsea third-graders on the Iowa reading test rose from the 30th to the 41st percentile.
- Since 1989, the percentage of high school seniors taking SAT tests has risen from 24 to 44 percent; and the average combined score has risen from 664 to 868.
- Since 1989, the percentage of graduating seniors who go on to post-secondary education has risen from 53 to 79 percent.

BU estimates that its direct and in-kind support for Chelsea's schools has to date totaled $10.5 million. In addition, the University has raised $11.5 million in private funds that have been used to enhance music and art education, to support after-school programs and to create a family literacy program. In 1997, the success of the BU/Chelsea Partnership led the School Committee to extend the University's contract through 2003.

- The ***Center for Science and Mathematics Teaching*** at Tufts has been working since 1986 to improve the teaching and learning of science and math at the elementary and secondary levels. It has pioneered the use of microcomputer-based lab (MBL) tools that help students measure and graph in real time a wide variety of physical phenomena.
- In 2001, faculty at Tufts University developed the ***Video Paper Builder***, software that allows teachers to work together to build a CD library of best teaching practices, including digital videos of outstanding teachers at work in the classroom, teaching materials, readings, etc.
- ***The Harvard Extension School*** offers an eight-course certificate in educational technology. It has recently expanded other course offerings for teachers, including new courses on mathematics theory and teaching algebra.
- ***The Boston University/Boston Public Schools Collaborative*** conducts math and literacy workshops and training for teachers in the city's public schools.
- Northeastern's ***Center for the Enhancement of Science and Mathematics Education*** (CESAME) is supporting the implementation of standards-based science and math education in elementary and high schools throughout New England.
- Northeastern's ***MathPower*** project provides individual planning, coaching and classroom support, as well as school-based group workshops, for math teachers in Boston public schools. In 1999-2000, 56 middle-school teachers from seven schools participated in the program.

Programs for Individual Students

The eight universities are a resource not only for school systems and teachers but for individual students. They provide numerous opportunities for education, enrichment, and assistance in making the transition to college. Once again, we cite here only a few examples.

- Through ***Boston College's CONNECTfive*** program, faculty members and students from Boston College's schools of education, social work, nursing, law, and management work with a network of community agencies to provide comprehensive support services to students in nine public schools in Boston's Allston-Brighton and Mission Hill neighborhoods.
- Boston College's ***Gardner Extended Service School*** (GESS) extends the school day at Gardner Elementary School by providing before-school, after-school and evening programs to students, family members and neighborhood residents. The program is a collaboration among Boston College, Gardner faculty and staff, the Allston-Brighton Family YMCA, and the Healthy Boston Neighborhood Coalition. Eight Boston College faculty members and 70 students currently participate in the program.
- ***Boston University Academy,*** founded in 1993, is an on-campus school for students in grades 8 through 12. The Academy offers a rigorous curriculum for talented students, including with opportunities to enroll in college courses.

- In 199-2000, 235 Brandeis students served as volunteers in after-school tutoring and enrichment programs, reading instruction and English language instruction for newly-arrived immigrant students in Waltham and surrounding communities.
- ***MIT's Educational Studies Program*** offers several enrichment programs to local students.
  - The ***Saturday Engineering Enrichment and Discovery (SEED) Academy*** is aimed at helping minority students from three high schools in Boston and Cambridge pursue careers in science and technology by helping them strengthen their skills in math, science and communications.
  - The MIT ***Science and Engineering Day Camp*** offers two one-week summer programs for seventh and eighth grade students at the Fletcher and More Schools in Cambridge. The programs are designed to introduce students to engineering and materials science.
  - ***Junction,*** an eight-week summer evening program, provides high school students with training in thinking and communication skills, math and science, and several elective courses.
- The ***Cambridge-Harvard Summer Academy*** provides individualized teaching to underachieving students in Cambridge. The University has committed $1 million to the program over a five-year period.
- Harvard's ***Chance*** program uses student volunteers to help students at Cambridge Rindge and Latin High School prepare for college. Harvard College students teach SAT prep courses, a writing workshop, and a course on creative learning techniques.

College Bound in Brighton and West Roxbury

Boston College's College Bound program, established in 1987, helps students in two racially, culturally and economically diverse Boston high schools — Brighton and West Roxbury — get access to and succeed in college. There are currently 75 students participating in the program.

Students participating in College Bound generally finish in the top 10 percent of their graduating class. Since the program's founding, students have gone on to attend 22 colleges, many of them in the Boston area. They have received scholarships and financial aid awards averaging more than $17,400 per student.

- Harvard is also a member of the ***Boston After School for All Partnership*** — a collaborative effort aimed at both increasing the number of children participating in after-school programs, and improving the quality of those programs. Harvard has committed $5 million to the Partnership over five years.
- Northeastern's ***Kellogg Partnership*** program provides student teachers for after-school and Saturday programs sponsored by six community-based organizations in Roxbury. Participation in this program is required for all undergraduate students in the School of Education.

- Northeastern's ***GEAR-UP*** program works with 150 low-income middle-school students and their parents, to inform them about opportunities for post-secondary education, and to help prepare them academically for college.
- ***The Eliot Pearson Children's School,*** located on Tufts' Medford/Somerville campus, offers a lab school setting to local children through the third grade.
- As part of Tufts University's ***Chinatown Partnership*** program, student volunteers from Tufts provide tutoring services throughout the school year to students at the Quincy Upper School in Boston's Chinatown.
- The ***Tufts Literacy Corps*** provides a team of 35 student teachers to six public schools in Medford and Somerville. Each tutor works with two students, two afternoons each week. Training for the tutors is provided through a yearlong series of weekly seminars conducted by a Tufts faculty member.
- ***The University of Massachusetts at Boston*** offers several programs for local public school students.
  - The ***Admission Guaranteed Program*** guarantees admission to UMass Boston for all students at Burke, Dorchester and South Boston High Schools who take college prep courses and maintain at least a 2.75 grade point average.
  - The ***Urban Scholars*** program provides academic and cultural enrichment, skill-building, and college and career guidance to 120 talented middle and high school students at selected Boston public schools.
  - ***The Health Careers Opportunity Program,*** a collaboration with the Tufts School of Medicine, offers an opportunity for students in UMass Boston's other pre-college programs to learn about and prepare for careers in medicine and public health.

Through these and other programs, the eight research universities help ensure that the young residents of the Boston area acquire the skills they will need to succeed in a knowledge-based economy.

X. Building More Attractive Communities

Just like the universities themselves, communities that want to attract and retain talent need to provide an environment that talented people will find attractive. For some people, the universities themselves are a magnet; even if they are not formally affiliated with one of the institutions, they enjoy the amenities that a university community provides. Others are attracted to the entrepreneurial environment, described in Part Two, that the universities have helped create. But the universities have also contributed in more direct ways to local community improvement programs.

- Boston University, for example, has been a major participant in efforts to revitalize Kenmore Square. BU is currently developing the 150-room Hotel Commonwealth, along with 40,000 square feet of retail space, in Kenmore Square.
- MIT has similarly been involved in efforts to improve the neighborhoods adjacent to its campus. MIT's recent contributions include:
  - Financing $28.5 million in neighborhood infrastructure investments, including street, signaling and sewer improvements.
  - Participating alongside city officials and community groups in neighborhood planning efforts such as the East Cambridge Planning Study.
- Northeastern helped stabilize its neighborhood by purchasing and redeveloping the troubled Ruggles Center project, now called Renaissance Park. The project includes a 165,000 square foot office and retail building, in which the University provides rent-free space for the Whittier Street Health Center. The building also houses a minority-owned pharmacy. The University has built a parking garage at an adjoining site at Renaissance Park; and development of a third site as either a hotel or commercial research and office space is now being explored.
- Tufts University is a partner in the Mystic Watershed Collaborative, a partnership of several communities that are cooperating in restoring this long-neglected waterway, and turning it into a major community asset. The project has attracted significant funding from both state and federal governments.
- Since 1980, UMB's Environmental, Coastal and Ocean Sciences program has been actively involved in the clean-up of Boston Harbor. Through their research and service on advisory boards, they have brought a multi-disciplinary approach to the clean-up effort, and are monitoring progress toward full restoration of the Harbor.
- Boston College has for several years been a partner in the Main Street program in Allston and Brighton, working with local merchants and neighborhood groups to improve neighborhood commercial areas and strengthen local businesses.

Promoting the Development of Affordable Housing

The growth of the Boston area economy has fueled the demand for housing throughout the region. As the price of housing has been bid up, it has become increasingly difficult for low- and moderate-income families to find affordable housing. The research universities have responded to this problem in three ways.

Several institutions have sought to increase the supply of on-campus and other university-owned housing. Such housing, as noted in Part Three, can enhance the universities' ability to attract talented students and scholars; but it can also reduce the demands that students place on a limited supply of affordable housing. Examples of such development include newly-constructed residence halls at Boston College, BU's Student Village project, the new on-campus residence hall at Brandeis, Harvard's new apartment complex in Allston, MIT's Simmons Hall and Pacific Street apartments, and Northeastern's Davenport Commons and Buildings G and H, and UMass Boston's planned on-campus housing. Between 1999 and 2004, the universities will have added living space for 6,400 students to the region's overall supply.

In addition to lessening the pressure on local housing markets by developing housing for their students, several universities have also contributed more directly to the development of affordable and market-rate housing in their communities.

- At three sites in the East Cambridge, North Cambridge and Cambridgeport, MIT has developed 700 units of housing for the elderly.
- As part of MIT's University Park development, 150 units of affordable housing and 124 market-rate units have been completed, and an additional 361 market-rate units are planned.
- As noted in Part Three, Northeastern's Davenport Commons project, in addition to student housing, includes 75 units for community residents.
- In 2000, under its "20/20/2000" program (described in detail below), Harvard University committed $20 million to support efforts by community-based housing organizations to develop affordable housing in Boston and Cambridge.
- Tufts recently acquired the Hillside School in Medford, and will renovate it for use as both faculty apartments and affordable housing.

The research universities, of course, cannot by themselves fulfill the region's need for affordable housing. But by housing a larger share of their own student populations, and by collaborating with local governments and community organizations in the development of affordable housing for community residents, the universities can contribute materially to the solution of this problem.

Developing Affordable Housing: The University as Partner

Among the more innovative examples of university participation in the development of affordable housing programs is Harvard's 20/20/2000 initiative. Launched in November 1999, the 20/20/2000 initiative created a twenty-year, $20 million revolving loan fund that is being used to help non-profit developers in Boston and Cambridge finance housing for low- and middle-income families.

Three local non-profit organizations administer 20/20/2000 loans, which can be used for property acquisition, pre-development costs such as planning design and permitting costs, construction financing or permanent financing. The interest rate on these loans is fixed at 2 percent. To date, non-profit developers have completed or have under development 1,675 units of affordable housing financed in part with 20/20/2000 loans. Examples of these projects include:

The Cambridge Affordable Housing Trust's purchase and rehabilitation of 65 apartments on Lancaster Street, using a combination of a 20/20/2000 loan, funds from the City of Cambridge and the federal government, and local bank financing.

Rehabilitation of 20 apartments on Hano Street in Boston by the Allston-Brighton Community Development Corporation, using funds from 20/20/2000 and several other sources.

Conversion of the former Longfellow School on Ruggles Street in Roxbury into 43 studio apartments for the elderly. The project, a joint venture of three local organizations, combines a 20/20/2000 loan, federal grants, and low-income housing tax credit financing.

Harvard's 20/20/2000 initiative builds on a history of University involvement in efforts to address local housing needs. In the 1970's, Harvard took the lead in developing 775 units of Section 8 housing in Boston's Mission Hill neighborhood; in 1997, the University sold this complex to an organization representing its tenants. In 1994, the University sold 100 apartments in Cambridge to Homeowners' Rehab, a non-profit housing group, for 30 percent of their market value; the deeply discounted sale helped increase the supply of affordable housing in Cambridge at a time when the repeal of rent control was placing upward pressure on rents. And in 1997, Harvard participated in the development of 94 units for the elderly and disabled at Putnam Square in Cambridge.

Along with 20/20/2000, Harvard launched two other initiatives in 1999. The University created the Housing Innovation and Policy Fund, which in 2000 and 2001 provided $915,000 in grants to 32 non-profit organizations, to support the development of new approaches to meeting affordable housing needs. The Allston Brighton Community Development Corporation, for example, has used HIP funds to survey non-residential buildings in Allston and Brighton, to identify those that might have potential for conversion to affordable housing. The University also created the Harvard Housing Advisory Committee, through which Harvard faculty provide advice and assistance to local non-profit developers.

Part Five:

Looking to the Future

XI. Helping to Secure the Region's Prosperity

As this report has shown, the Boston area's research universities have in recent years played an important role in the development of the region's economy. For several reasons, they could make an even greater contribution in the years ahead. There are, however, a number of serious challenges that both the research universities and the broader regional community will have to address, if the universities are to realize their full potential as major contributors to the continuing development of the Boston area economy.

The Growing Role of the Research Universities

There are several reasons to expect that the research universities' role in the region's economy will continue to grow over the course of the next decade.

The growing importance of science and technology

Over the past fifty years, science and technology have steadily become more and more important as generators of economic growth. Lewis Branscomb and Fumio Kodama have found that "Industry dependence on innovation has been accelerating dramatically since the Second World War, for several reasons." Engineering is now much more firmly grounded in science, making it more systematic and more predictable; "in many fields, inventions can be systematically managed into being." Universities have played a central role in expanding the base of knowledge on which today's economy is built, and will continue to do so.[32]

The areas of scientific and technological innovation that are most likely to generate new economic growth over the next ten years include several in which the Boston area's research universities are especially strong — the life sciences, biomedical research, information technology, photonics and nanotechnology. The continuous flow of ideas and talent from the universities into these and other fast-growing industry sectors will help fuel the growth of the region's economy.

The growth of research spending

In a more immediate sense, the eight universities' ability to contribute to the growth of the region's economy will be enhanced by the growth of research spending. Since the late 1990's, Congress has steadily increased federal funding for biomedical research; by 2003, federal support for such research will have doubled over five years. The promise of new fields such as proteomics and medical nanotechnology is likely to keep federal funds flowing.

As new issues emerge, moreover — such as concerns about climate change, bioterrorism, new forms of warfare and the impact of globalization — federal agencies will seek the universities' assistance in understanding and addressing them. ***The diverse strengths of the Boston area's universities mean that the region is well-positioned to respond to changing research priorities.***

[32] Branscomb and Kodama, op. cit., pp 8-9, 16-17.

As discussed below, however, near-term growth in federal research funding in selected areas does not mean that the Boston area and its universities can take for granted the continued growth of federal research revenues.

Because of the cost and complexity of research in many of these emerging areas, moreover, major corporations may increasingly be inclined to limit their costs and risks by establishing partnerships with universities and other institutions. Such partnerships could represent a growing source of support for the Boston-area research universities and their affiliates.

The growing importance of collaboration

The increasing complexity of emerging areas of scientific and technological development today makes it less and less likely that any one institution will possess all of the intellectual and human resources needed to advance the frontiers of knowledge. As discussed in Part Two, progress in fields like medical nanotechnology, for example, depends on the successful collaboration of physicists, chemists, engineers, physicians, and others. The multiplicity of research universities, institutes and hospitals in the Boston metropolitan area — and the diverse strengths they bring to the process — offer opportunities for collaboration and synergy that no other U.S. region can match.

Moving from lab to marketplace

Excellence in science and technology will, however, have only a limited impact on economic growth, if it is not tied closely to institutions, resources and services — ultimately, a whole culture — that supports commercialization. During the past decade, Boston-area universities that had long been active in technology transfer — including MIT, Harvard and Boston University — have further developed their ability to move new knowledge from the lab to the marketplace. Others that a decade ago were not very active in this area — including Northeastern, Brandeis, Tufts and UMass — have begun during the past decade to pay much more attention to opportunities for commercialization.

This is not solely a matter of becoming more skilled in managing the formal technology transfer process. As described in Part Two, the universities have taken many other steps to encourage and support the translation of academic work into new business development — training students in entrepreneurship, providing technical assistance (and in some cases, funding) to faculty members who want to start new businesses, investing in local venture capital funds, providing "incubator" space for start-ups, etc.

Continuation of these efforts will mean that in the years ahead, all of the universities should become more efficient in translating new knowledge into new products and businesses. ***Not only will university research spending increase, but every dollar spent on research will generate a greater economic impact, in terms of license agreements, new business start-ups, licensees' investments in R & D, and jobs created.***

Globalization

Predicting the course of economic evolution is a notoriously difficult task. But one trend that seems certain to continue is that well into the future, international trade and investment will grow more rapidly than America's domestic economy. The prosperity of U.S. cities and regions will increasingly depend on their connections to the global economy.

The eight research universities have helped in a variety of ways to build the Boston area's connections to the global economy:

- By educating their students to live and work in an increasingly integrated world;
- By conducting and disseminating research on a wide range of global issues, such as international development, energy policy and climate change;
- By bringing students and scholars from around the world to the Boston area;
- By fostering the development of informal personal, professional and business relationships among graduates in the U.S. and in other countries;
- By developing their own operations in other countries;
- By helping to attract major global companies such as Novartis to the Boston area.

Through these and other means, ***the research universities will over the course of the next decade continue to develop the region's ties to the global economy — at a time when those ties are likely to be more valuable than ever.***

Developing the region's human capital

In today's idea-driven economy, the quality of a city or a region's human capital — as measured by the level of educational attainment of its population — is the single most important determinant of its rate of economic growth. In a region in which the most human capital-intensive industries have been the primary sources of growth, this dependence seems certain to grow.

The eight research universities will play a central role in satisfying this growing demand for talent — both by educating Boston area residents, and by attracting talented students and scholars from all over the U.S. and the world to the area.

This growing demand for human capital development is not, however, limited to formal higher education — undergraduate, graduate and professional degree programs. In today's ever-changing economy, there is a rapidly growing demand for "lifelong learning." The universities' continuing education programs represent an especially valuable resource for meeting this demand. Moreover, as noted in Part Two, the research universities bring to the process of continuing education a depth an breadth of resources that other educational institutions cannot match. ***They are thus likely to play an increasingly important role in ensuring that the knowledge and skills of the Boston area's college-educated work force keep pace with the demands of a rapidly-evolving economy.***

The Challenges Ahead

For the reasons outlined above, the eight research universities could play an even greater role in the Boston area economy of the future than they are play in today's. There are, however, a number of challenges that the universities and the broader regional community must face together if the universities are to realize this potential.

Continued support for research

While federal funding for research seems certain to increase during the next few years, continued growth in federal support for university research cannot be taken for granted. Pressures to curb (or even reverse) the growth of research spending could intensify in the future, especially as Washington struggles to cope with the effects of slower economic growth, tax cuts and increased defense spending.

Declining federal support for basic and applied research could seriously erode the research universities' contribution to the growth of the Boston area economy. It would reduce overall university employment and spending. Even more important, it would reduce the eight universities' ability to attract and develop talent — to create new knowledge — and to stimulate private investment in new businesses.

In 1996, Amy Candell and Adam Jaffee of Brandeis University assessed how a hypothetical 35 percent decline in federal research spending between 1995 and 2000 would affect the economy of Massachusetts. They concluded that by 2010, such a decline in federal spending would reduce the Commonwealth's gross state product by $4.8 billion (in 1995 dollars) — a reduction of 1.8 percent — and would reduce total employment in Massachusetts by nearly 50,000, or 1.4 percent.[33] Given the growth in research spending since 1996, a similar cutback over the next five years would probably have an even greater impact on the Bay State economy.

Ensuring the continued growth of federal investments in research should thus remain a top priority for the region's representatives in Washington. It is, of course, not just the health of the Boston area economy that is at stake here. Economists have repeatedly demonstrated that the long-term payoff from federal research spending is extraordinary.[34] This is one case where what is good for the Boston area is unequivocally good for the nation.

Unlike the federal government, state government in Massachusetts has not to date been a major source of funding for university research; as noted in Part Two, state and local sources account for less than one-half of one percent of all research spending at the eight universities.

Obviously, the universities cannot look to the Commonwealth to supplant federal agencies as a source of research funding. However, strategically targeted state investments could help ensure that Massachusetts universities can maintain their contribution to the state's competitiveness.

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[33] Amy Candell and Adam Jaffe, "The Regional Economic Impact of Public research Funding: A Case Study of Massachusetts," in Branscomb, Kodama and Florida, op. cit., pp. 525-526.

[34] See, for example, a report prepared by a group called Funding First, *Exceptional Returns: The Economic Value of America's Investment in Medical Research* (New York: The Lasker Foundation, May 2002).

Through its New York Science, Technology and Academic Research (NYSTAR) program, for example, New York State has helped finance new research facilities that have enabled both public and private universities expand their research capabilities in fields such as structural biology and nanotechnology. A similar program could help Massachusetts institutions maintain their leadership, and compete more effectively for limited federal research funds. Similarly, support for university-industry research partnerships, along the lines that many other states provide, could help Massachusetts universities attract corporate research funding, and accelerate the transfer of new knowledge to Massachusetts companies. State support for research may also play a critical role in certain areas in which federal funding is severely restricted or unavailable.

The quest for space

Despite the increases in productivity that have resulted from more extensive use of information technology, university research is still a space-intensive activity. Real growth in the universities' research enterprise will over time require the development of additional space.

Some of this need for space can be met through modernization and more efficient use of existing facilities, or through on-campus construction of new facilities. However, many of the region's research universities have relatively little land available on which to develop new facilities. This means that to grow, universities will sometimes need to build new facilities outside the historic boundaries of their campuses.

While such expansion inevitably raises issues for the universities' neighbors, it is essential to their ability to grow (or even maintain) their contribution to the economies of their home communities, the Boston area and the state. Boston-area universities and their home communities would both benefit from the creation of a framework that simultaneously respects local concerns and allows the institutions to respond quickly to emerging needs and opportunities — for example, through the designation of "institutional zones" within which universities can expand on an as-of-right basis.

For some universities, development of the space needed to support a growing research enterprise may also represent a financial challenge. Given the long-term importance of university research to the growth of the region's economy, state officials should consider working with the universities to devise new approaches to financing the development of research facilities.

Supporting entrepreneurial development

As described in Part Two, the ongoing development of programs and services designed to encourage and support the entrepreneurial initiatives of faculty and students, and to assist entrepreneurs throughout the broader regional community, has been one of the most significant trends emerging from the eight research universities over the course of the past decade. The universities' pervasive impact is highlighted, for example, by the fact that half of fifty Boston- area startups that attracted the most early-stage financing in 2002 have some significant connection to one or more of the eight institutions.

Despite the progress that the universities have collectively made in this area, they cannot afford to rest on their accomplishments. University support for entrepreneurship is not only important for the development of new businesses in the region — it is vital to the universities' long-term success in attracting and retaining the most talented faculty, researchers and students. The universities therefore need to continue to reinforce their efforts in this area — for example, by expanding entrepreneurial education and training programs, by providing more "bridge financing" to faculty members engaged in pre-commercial development work, and by extending their support for new business development into the surrounding communities.

Preparing the region's young people for life in a new economy

More than ever, the knowledge- and idea-driven economy that the research universities are helping to create in the Boston area will in the years ahead require workers with higher education and skills. As this report has shown, the universities are already a major source of skilled personnel for the Boston area's leading industries. To take advantage of the opportunities that the universities and the new economy offer, however, the region's young people will need a solid grounding at both the elementary and secondary levels.

As Part Four of this report shows, the eight research universities are already deeply involved in efforts to improve the quality of elementary and secondary education in the Boston area, and to expand the opportunities for learning available to the region's young residents. In order to ensure in the year ahead that all of the region's young people have a chance to succeed in the new economy, universities, schools and communities will have to build upon and expand this track record of collaboration.

Working with communities

As they have done for many years, the research universities need to work with local officials and community groups to address such issues as the impact of students on local housing markets, the impact of increased employment and enrollment on traffic, and the development of new facilities.

Communities should not, however, view the continued growth of the universities simply as a problem to be managed. As this report has documented, research universities can be an invaluable resource for communities that are seeking to develop new businesses and jobs, to improve their schools, to create an environment that will help them attract and retain talent, and to expand learning opportunities for adults. Local officials and community groups and individual residents should be sure to take full advantage of all of the resources the universities have to offer.

Realizing the research universities' full potential for building the Boston area economy will require an active partnership between universities and communities.

For information about the universities in this study, please contact the individual offices of government, community, and public affairs as listed below:

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