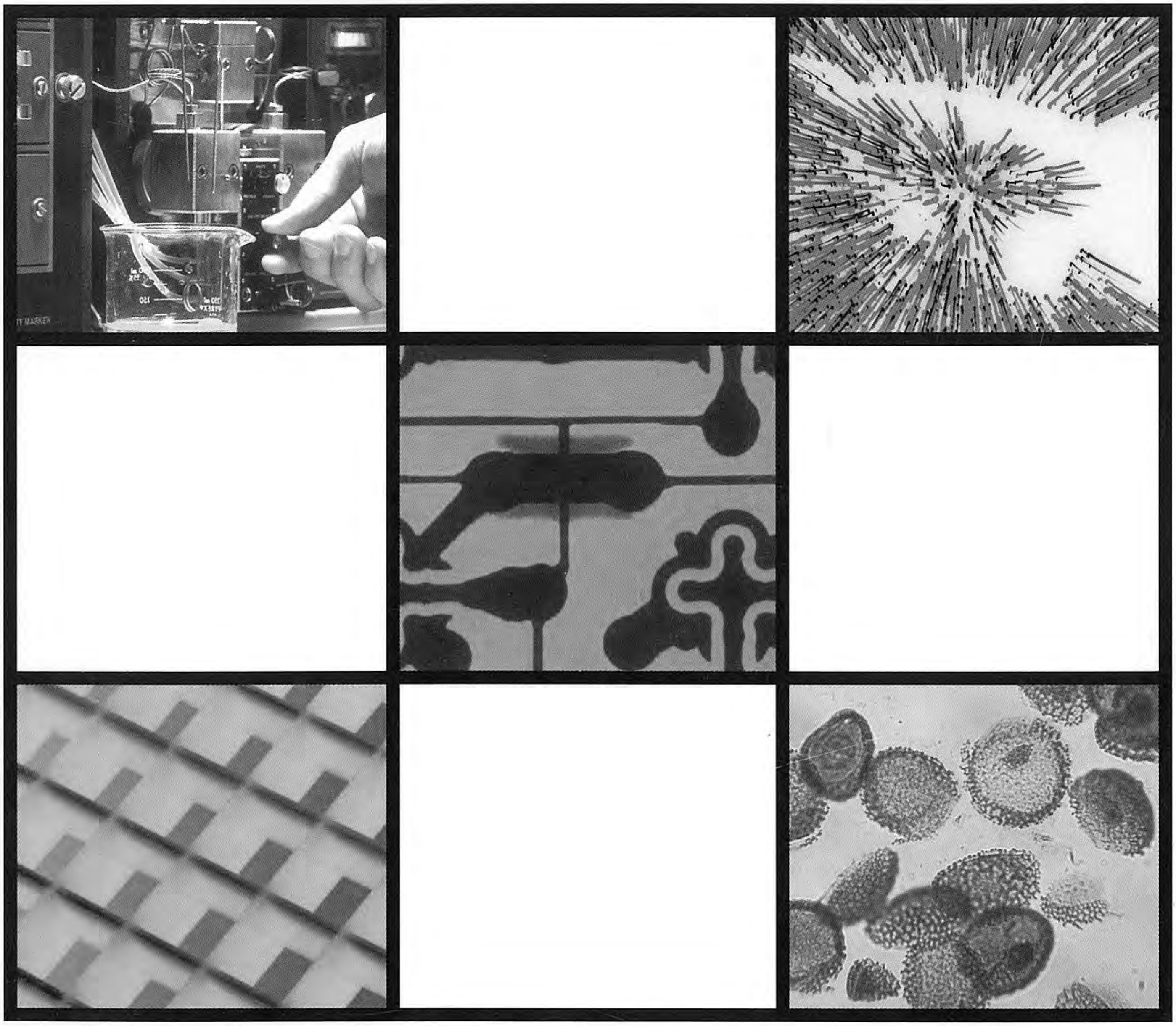
Massachusetts TECHNOLOGY Collaborative



Planning for change Preparing for growth

FEBRUARY 1996

Massachusetts TECHNOLOGY Collaborative

February 29, 1996

Dear Friend:

Massachusetts has long been blessed with an unparalleled concentration of the world's best known and respected research institutions — universities, medical centers, non-profit technical organizations, and technology-intensive firms. Collectively, they have been at the core of the state's economy, providing jobs and growth, attracting capital and serving as a magnet for the world's best students, teachers, managers, entrepreneurs, and workers.

Historically, there has also been a synergy between the excellence of our research institutions and federal research funding. Excellence has attracted funding which has increased excellence which has attracted more funding. As a result of this singular success in obtaining federal funds, Massachusetts institutions are more dependent on federal support for research and development than institutions in any other state. Federal departments and agencies spend approximately $3.6 billion per year on Massachusetts-based research, constituting 72% of our academic research and 27% of our industrial R&D.

Recent events, however, signal a significant reduction in the federal government's support for scientific, engineering and medical research.

The factors underlying proposals to reduce federal technology funding cannot be regarded as either partisan or fleeting. They include, most importantly, changing perceptions across the political spectrum of the proper role for the federal government in the economy, a general acknowledgment of the need to control the structural federal deficit, the end of the cold war and its impetus for defense-driven scientific research, the absence of an effective political constituency for long-term investments in research and development, and a less-than-complete understanding among policy makers of the importance of research investments to the nation's economy and security.

To stimulate a public dialogue about the significance to the Commonwealth of proposed federal technology funding reductions and the full range of strategies available in response, the Massachusetts Technology Collaborative (MTC) convened a special working group of leading industry, university and government representatives in July of 1995. Acting upon the recommendation of the working group, and with the advice of a committee of esteemed local economists, MTC selected the Economic Resource Group, Inc. (ERG) to conduct a study of the implications of proposed federal technology funding reductions on Massachusetts research institutions and our economy.

Today, we are pleased to release the final report of that study, **Planning for Change/ Preparing for Growth: *Implications of Reduced Federal Research Spending for Massachusetts***. This report was prepared under the leadership of ERG Principal and Brandeis Economics Professor Adam Jaffe, with significant involvement by MTC Board and advisory committee members, staff and consultants.

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An initiative of the Massachusetts Technology Park Corporation, an independent instrumentality of the Commonwealth of Massachusetts

The MTC/ERG report reviews in detail the manner and extent to which academic and industrial research and development are central to the Massachusetts economy. Massachusetts is the most "research intensive" of the major industrial states, with research and development expenditures representing almost 6% of the Commonwealth's Gross State Product. In addition, research activities create significant commercial benefits that are distributed widely throughout our economy. The report details the near-term direct and induced benefits of research expenditures, as well as the important longer-term spillover effects of increased economic activities in the Commonwealth.

In particular, the report documents that although there are readily available channels for the wide distribution of technological know-how, commercialization of new technology tends to occur near the source of its development. This "localization effect" does much to explain the critical importance of a strong research base to the Massachusetts economy. It also supports the contention that reductions in research activity can have a cumulative and lasting effect on the Commonwealth.

The unique and substantial contribution of research and development activity to the strength of the Massachusetts economy compelled an objective analysis of the magnitude of proposed reductions in federal technology spending and their implications for our economy. This analysis was based on very conservative assumptions concerning future behavior and on the best budget projections available at the time given an uncertain and volatile political environment. It did not include, for example, an accounting of the significant, yet indirect, effects of proposed Medicaid and Medicare reductions on medical research. It reveals a possible worst case scenario of a reduction in federal funding of up to 34% in real terms over the years 1995 to 2002 and a consequent reduction in employment and economic activity of between 23,000 to 50,000 jobs and a decrease in the Gross State Product of up to $4.8 billion by the year 2010.

It is worth emphasis that this is a worst case forecast. It is a snapshot in time. It is utilized to illustrate the deep impact of academic and industrial R&D on the Massachusetts economy, and the sensitivity of the state's research enterprise to changes in federal spending. It is also designed to be an extreme point on a continuum for comparison of several scenarios for potential federal funding reductions. But, it need not occur. In fact, there is already solid evidence that the actual declines in economic activity may be less than projected because federal research funding reductions may not be as deep as originally modeled. As suggested in this document, well coordinated and planned initiatives to influence decisions in Washington concerning funding for science and technology can be successful.

For example, this fiscal year, through a concerted effort stimulated by Governor Weld and joined by the Governors of other states where research and development is a critical component of economic growth, actual reductions contained in appropriations bills for federal support of military non-civilian research were substantially less than had been proposed in the 1995 Congressional budget resolution. DoD research support, originally projected to decrease by 3.12% from 1995 to 1996, instead increased by 2%, corresponding to about $111 million in additional funding for Massachusetts compared to what was modeled. Similarly, medical schools, hospitals and the biomedical industry marshalled their resources successfully to effect an **increase** of 5.8% in funding for the National Institutes of Health, the nation's largest civilian R&D account. If these results portend future decisions concerning federal funding of research, then the estimates of losses in employment and Gross State Product contained in this Report will be considerably less. As a result of this recent appropriations activity in Congress, Dr. Jaffe has recalculated his findings and concludes that if this year's pattern continues, the most severe downside risk in 2010 would be 46,000 jobs and $4.5 billion of the GSP.

Despite some positive trends, however, it is inescapable that we are entering a new era in federal funding of science and technology. For Massachusetts, there are great potential risks. The MTC/ERG report concludes that the effects on our major research institutions will be especially severe.

One particularly disturbing question is whether proposed spending decreases will occasion not simply a quantitative reduction in research and development activity and output but also a *qualitative* reduction in the prominence and stature of our institutions? If reduced federal funding were to result in a decline in the preeminence of the Commonwealth's institutions of higher learning and research and in certain significant areas of technical education, this decline could generate still further reductions in economic activity in a reversal of the complex and fragile calculus of excellence that has historically been a defining characteristic of our state as a world center for research and development.

Another potential area of concern for the future is that our research institutions may do less well in the competition for reduced federal resources. Since the Commonwealth's research organizations are among the very best in the world, any allocation decisions that emphasize criteria other than merit will work to their disadvantage.

The challenge of adapting to this new reality is to minimize the negative impacts and to seize the opportunity to make ourselves even more competitive than we were before. We need to take actions which acknowledge the change and prepare us for growth. And we need to think of ourselves as a community in ways that we have not done so before.

Here are five steps which we at MTC propose for consideration.

The first and most obvious is to institutionalize a region-wide monitoring system so that we remain current on developments in Washington. How the federal government makes its technology funding determinations over the coming years — and how our research institutions react to those funding determinations — will to a significant degree identify the policy choices confronting the Commonwealth. To this end, Massachusetts must develop closer working relationships with and among its research institutions, new forums for sharing information and addressing issues of mutual concern, and better means of measuring the implications of developments in the federal policy arena. MTC is committed to undertaking new initiatives to extend the efforts of the working group assembled to advise us on the ERG report, to monitor federal developments, to explore public and private interventions to strengthen our preeminent research enterprise, and to ensure an on-going, high level commitment to science and technology policy.

A second area for action is the preservation of the maximum federal funding for the region's research institutions. With due regard to the legitimacy of the concerns that underlie the new era of federal spending, there is a compelling case for the strategic importance to the nation of maintaining significant federal investments in technology research. We now have some positive evidence that when this argument is presented effectively it can influence federal decision-making. MTC, working closely with the key Commonwealth and regional agencies, the Massachusetts and New England Congressional delegations, and other technology and business-oriented organizations and associations, will actively encourage and support a collaborative effort to advance shared interests.

Third, we need to develop new strategies to influence federal technology funding determinations. In Washington, actions calculated to preserve merit-based funding allocations will work to the benefit of Massachusetts institutions. In the Commonwealth, we need to respond to federal funding reductions by making Massachusetts research organizations responsive and even more attractive in an altered funding environment. For example, we should examine the potential benefits of increased facility-sharing among research institutions with common scientific objectives, public capital matching funds for federal grants, and an extension of collaborative actions that go beyond Massachusetts and include the New England region.

It is reasonable to project, however, that notwithstanding any action we may take, Massachusetts institutions will receive less federal research funding in real terms than they have in the past. To maximize the value of this support, to do more with less, the MTC/ERG report suggests that, as our fourth and fifth action steps, we develop new strategies in two additional areas that are calculated to enhance the capacity of our innovation system.

Thus, the Commonwealth should seek to increase the efficiency of technology transfers from research institutions to the industrial sector. More facile information flow and networking between academic researchers and industrial colleagues, greater incentives and support for cooperative technology licensing offices, encouragement of cooperative research and development programs, and evaluation of the current rules governing allowable relationships between academic institutions and commercial partners are all fertile areas for consideration. These types of activities exploit the tendency of product commercialization to occur proximate to the research base.

In addition, the Commonwealth should seek to capture a greater portion of wealth and job-producing activity that results when a technology moves from research and development to production. Massachusetts has done much in the past few years to improve the conditions which enable industrial growth and expansion. Tax rates have been lowered and regulatory burdens eased. In choosing to compete to retain a greater portion of this production activity, MTC is committed to working closely with key technology industry clusters to make our economic environment still more responsive to the particular needs and interests of our technology-intensive firms.

The Massachusetts Technology Collaborative urges you to study this report and its implications for the economic future of the Commonwealth and extends an open invitation to all interested parties to join with us as we respond to this latest challenge.

There is no denying that in the federal technology funding arena, the future will be unlike the past. Preparing prudently for the future is not a partisan issue; it must be a common goal. Acting now, working together, thinking ahead, and responding with an awareness of the realities, we can minimize the downside dangers and maximize the potential for an internationally competitive Massachusetts economy driven by the highest quality research institutions and technology entrepreneurs in the world.

In closing, we would like to thank all who participated in the preparation of this report, many of whom are acknowledged directly in the document.

Sincerely,

Joseph D. Alviani
Executive Director

PLANNING FOR CHANGE/ PREPARING FOR GROWTH

Implications of Reduced Federal Research Spending for Massachusetts

Prepared by:

Dr. Adam Jaffe
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for

Massachusetts TECHNOLOGY Collaborative

February 1996

Table of Contents

Table of Figures

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Executive Summary

Scientific and engineering research and the high-technology industries which develop as a result of that research are at the core of the Massachusetts economy. In 1993, *expenditures on research and development in Massachusetts totaled about $9.6 billion, representing almost 6% of Gross State Product*, the highest "research intensity" of any of the major industrial states. The research-intensive sectors of higher education and health care, and the computer, electronics, aerospace, scientific instrument and research-services industries are major sources of employment in the Commonwealth and important engines of future growth. In addition to being unusually research-intensive, the Commonwealth is more dependent than other states on research funding from the federal government. *Federal departments and agencies fund approximately 72% of university research and 27% of industrial R&D, compared to nationwide averages of 60% and 19%, respectively.*

In the aggregate, the federal government currently spends approximately $3.6 billion on R&D at Massachusetts firms, universities, and other non-profits organizations. The growth in federal research funding over the last decade has been a boon both to individual Massachusetts institutions and to the state economy overall. But this heavy dependence on federal research funding makes Massachusetts particularly vulnerable to reductions in federal research support that are likely to occur over the next several years. An analysis of the potential effects of these reductions reveals some disquieting projections:

- Overall federal support of research in Massachusetts could fall by as much as 34%, after adjustment for inflation, between 1995 and 2002.

- This decline in support will have a greater impact on the state economy than other reductions in outside funding, because of the "spillover" effects of university and hospital research on high-technology industries.

- Projections indicate that federal funding cuts will reduce Massachusetts employment by 7,000 to 17,000 jobs in 1997 and 23,000 to 50,000 jobs in the year 2010 relative to what otherwise would have occurred.

- The corresponding reduction in Gross State Product could eventually be as much as $4.8 billion per year.

- Increases in other funding sources are unlikely to replace completely the lost federal funding, and macroeconomic benefits flowing from the overall balanced federal budget will not eliminate the adverse economic consequences for the Commonwealth.

- Within these overall reductions, specific institutions in the university and hospital sectors will suffer significant dislocations, most likely resulting in financial strains, delay and cancellation of construction programs and reductions in research faculties.

Projections of federal research spending

While it is impossible to know with certainty what future federal research expenditures will be, Congress has provided one blueprint for future spending in its 1995 budget resolution. To arrive at the projections set out above, two scenarios were constructed: a "declining spending" scenario based on the Congressional plan, and a business-as-usual, what we refer to as our "baseline" scenario, which estimates spending levels that *would have* prevailed given normal economic growth under the previous policy regime.

Under the **declining spending scenario**, we estimate that overall federal support of research at firms, universities and other non-profits would fall from $3.6 billion in 1995 to $3.0 billion in 2002, a reduction of 16%. After adjustment for expected inflation, the 2002 level would be 34% less than in 1995. If this spending level is compared to the **baseline** forecast, the **declining spending scenario** represents a 35% cut in federal research spending for Massachusetts relative to what was projected to occur in 2002.

Economic impact of academic research

In assessing the economic implications of these large reductions in external research support, it is important to consider the "spillovers" created by research. There is considerable statistical and anecdotal evidence that the research enterprise in Massachusetts, particularly the more "basic" research conducted at universities and other non-profit research institutions, creates significant commercial benefits that are distributed widely through the local economy.

The most visible manifestation of research spillover is the start-up of new firms based on technology originating in universities or hospitals. Because of their close links to researchers, start-ups are much more likely to be located within the state than other firms using academic technologies. For example, 60% of start-up companies licensing MIT technology are located in Massachusetts. An MIT survey of its licensees reveals that these firms alone have invested hundreds of millions of dollars in development of technologies that originated in the academic sector and created thousands of jobs. In addition to start-ups, academic research generates commercial impacts through university-industry research centers, other forms of networks and collaboratives, consulting connections between faculty and firms, and graduates who take jobs with firms within the state.

Cumulatively, reductions in federal research support affect the economy through three important channels:

- The diminished flow of dollars into the state directly reduces wages and the purchase of other goods.
- The reduction in academic research *induces* a further reduction in industrial R&D in the state, because university and other non-profit research stimulates industry research designed to develop and commercialize more basic research results.
- After some years, the direct and induced reductions in research leads to a reduction in the rate at which Massachusetts firms introduce new products and processes, slowing the growth of such industries as computers, electronic and communication equipment, and medical and scientific instruments.

Estimates of overall economic impact in Massachusetts

The combined impact of these direct and indirect effects would be considerable. We estimate that the *short-run* impact of the **declining spending scenario** would be a reduction in Massachusetts employment of about 17,000 jobs in 1997, relative to the **baseline** forecast. A less extreme scenario, in which federal spending in each category is simply held at a constant level with no adjustment for inflation, the "constant spending" scenario, results in a projected employment reduction of about 7,000 jobs relative to the baseline in 1997.

Over time, this direct effect would fade, but impacts due to reductions in innovation and the resulting industry growth would increase gradually. We estimate that Massachusetts employment in the year 2010 would be about 50,000 jobs fewer in the **declining spending scenario** and about 23,000 jobs fewer in the **constant spending scenario** relative to the **baseline** forecast. Corresponding to these reductions in forecasted employment are reductions by the year 2010 in Gross State Product of $4.8 billion per year under the **declining spending scenario** and $3.0 billion per year in the **constant spending scenario** expressed in inflation-adjusted 1995 dollars. *The reductions in Gross State Product are more than proportional to the employment reductions, reflecting the fact that the jobs lost in research-intensive sectors are, on average, higher-paying than those in other sectors.*

There is substantial support for the notion that balancing the federal budget will reduce future tax burdens, and perhaps lower interest rates and thereby stimulate investment. We have not included in our model potential beneficial effects on the Massachusetts economy of these macroeconomic forces. It seems unlikely, however, that these beneficial effects would offset the negative impacts that we have identified, because of the disproportionate dependence of the Massachusetts economy on research and the above-average dependence of Massachusetts research on federal funding.

Impact on specific sectors and institutions

These overall effects on the Massachusetts economy are modest, yet significant, reductions in the rate of economic growth that would otherwise occur over this period. For the specific institutions which provide the underpinning of our knowledge-based economy, however, the impacts are much more severe. Universities, hospitals and other non-profit research institutes will experience significant absolute reductions in federal research support if the **declining spending scenario** we have analyzed occurs. It seems unlikely these institutions will be able to offset a large fraction of these cuts with other sources of funding, given the dominant role of federal support in these institutions' overall budgets, the "complementary" nature of federally funded and industry-funded research, the relatively bleak outlook for industry research spending, and (for hospitals) the simultaneous reductions in revenues from patient care and Medicare/Medicaid reimbursement receipts.

In the short run, this is likely to lead to reductions in research activities and financial difficulties for some of the affected institutions. In the long run, it is likely to result in reduced construction of new facilities and shrinking research faculties.

The effects in industry are more diffuse. In only one sector, aerospace, does our analysis suggest absolute declines in research spending and overall output under the **declining spending scenario**. Research and engineering, computer, electronics and scientific instrument firms will experience reductions in the growth that would otherwise occur in their R&D and output. These reductions will ripple through the state economy, resulting in modest reductions in the growth of the construction, business services and retail sectors.

Beginning a dialogue on the Massachusetts research infrastructure

Academic research institutions and research-intensive firms are important pillars in the foundation of long-term economic growth and employment in the Commonwealth, producing skilled graduates, new scientific and technological knowledge and commercial innovations essential to the comparative advantage of Massachusetts in a knowledge-based international marketplace. The research funded by the federal government, both in the non-profit sector and through industrial firms, is a critical component of this overall scientific and engineering enterprise. Proposals now being considered by the Congress and the Administration to reduce or eliminate federal funds for specific programs in the area of science and technology will pose substantial challenges to institutions and firms that serve as engines of economic growth in the Commonwealth.

The complexity and delicacy of the innovation system suggests that our coarse, macroeconomic analysis could in fact *understate* the severity of the potential consequences. It is possible that funding reductions of the magnitude being contemplated will alter fundamentally the character of some of Massachusetts' premier research institutions, leading to a disruption in their contribution to the economy that goes far beyond the smooth, proportionate effects modeled herein.

With this report, the Massachusetts Technology Collaborative seeks to draw the attention of public policymakers, as well as private stakeholders, to these challenges. This report should be seen as the beginning of a dialogue among academic, hospital, industrial and government leaders to determine ways in which the transition to a new federal research funding paradigm can be accomplished with the least damage to these remarkable and important institutions and to the Massachusetts economy.

I INTRODUCTION

I.A Objectives and overall approach

The Massachusetts economy relies heavily on academic research institutions and research-intensive firms, which produce skilled graduates, new scientific and technological knowledge, and commercial innovations that are the keys to economic growth in a knowledge-based world. Recent studies by the Massachusetts Technology Collaborative (MTC) and by Michael Porter of Harvard University and The Monitor Company identify key industrial clusters underlying the Massachusetts economy, most of which are dependent on a strong scientific and technological base.[1] A critical component of that base is research funded by the federal government, both in the non-profit sector and in industrial firms.

Indications are that federal spending in support of research will decline over the next several years, although the precise magnitude of the reductions is uncertain. Given the significance of this funding for the Commonwealth, such reductions pose serious risks for the Massachusetts economy. This report analyzes the mechanisms or pathways by which research activities, particularly in the academic sector, affect the economic performance of the Commonwealth in the short and long run. We then consider alternative "scenarios" for federal funding of research in Massachusetts between 1996 and 2002, and discuss the implications of these different scenarios for different categories of research institutions. Combining our modeling of the economic impact of research activities and our scenarios for future research funding, we develop quantitative estimates of the impact of different levels of funding cuts on the Massachusetts economy as a whole, as well as on particular industrial sectors. It is hoped that understanding the mechanisms that link research activities and the economy, and quantifying the shocks that the research infrastructure will suffer in coming years, will provide a basis for discussion among the many affected stakeholders about the range of public and

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[1] These studies include: *Choosing to Compete*, Executive Office of Economic Affairs, 1993; *Technology and Economic Growth: The Structure and Performance of Technology-Intensive Industries*, Massachusetts Technology Collaborative and Nexus Associates, 1995; *Technology and Economic Growth: The Role of Research Universities*, Massachusetts Technology Collaborative and Nexus Associates, 1995.

private actions that could be undertaken to deal with the changing research environment.

The report itself is an outgrowth of an effort undertaken by MTC and the Executive Office of Economic Affairs (EOEA), the objectives of which are to examine the role of science and technology in fostering economic growth in Massachusetts, with the emphasis on identifying the needs of the technology-intensive sectors of the state's economy, and the development of policy initiatives to ensure the continued health and vitality of the technology enterprise in the state. In a broader sense, then, the project is devoted to fostering dialogue among representatives of the Commonwealth's academic research institutions, leaders of its technology-based industries, and public and private policy makers. It is anticipated that through the collective participation of these stakeholders, the mechanisms by which government research support affects the Massachusetts economy in the long run will be better understood. As a consequence, it will allow for the creation of a framework for thinking about public and private actions to preserve the scientific and technological strength of the Commonwealth, and also maximize the contribution made by science and technology to our economic growth. Such a cohesive, systematic approach to private and public policy related to scientific technology would be important under any circumstances, but is becoming critical in the face of significant external shocks.

Most of the long-run effects of research activities are indirect and difficult to quantify. Nonetheless, there is a substantial body of research that identifies and quantifies or partially quantifies important pathways by which government research support leads to increased innovation, birth of new firms, creation of jobs, and increases in sales and profits for high-technology firms. The available research varies in the degree to which these effects are analyzed in systematic and quantified ways. At one end of a continuum are qualitative and anecdotal information about the role of research institutions and their interactions with other parts of the economy. At the other end are quantitative statistical estimates of the ultimate economic impact of research activities. Between these two extremes lie a variety of quantitative data that cover certain aspects of the impact of research activities, but which cannot be translated directly into economic measures such as sales or employment. In order to present as complete a picture as possible given the limitations of existing research, we rely to some extent on all of these sources of information.

Sections II and III of the report present a quantitative description of the overall role of research enterprises within the economy of Massachusetts, along with qualitative or descriptive information about the pathways by which this research activity affects the broader economy. In Section IV, we use statistical estimates of the impacts of research, in combination with a model of the Commonwealth's economy, to provide estimates of the overall economic impact of proposed reductions in federal research spending. Section V suggests some of the issues which must be considered in formulating public and private policy to strengthen the infrastructure of science and technology.

I.B The scope of the report

The federal government funds research in universities, teaching hospitals, and other non-profit institutions, through the National Institutes of Health, the National Science Foundation, the Department of Defense, and other agencies including the National Aeronautics and Space Administration and the Department of Energy. It also funds research at industrial firms, primarily through the Department of Defense. Proposals currently under discussion to balance the federal budget by the year 2002 presume that there will be substantial reductions in this research support. We analyze two scenarios designed to reflect a range of research funding levels under the new budget environment. The first, which we call the "declining spending" scenario, is based on the 1995 Concurrent Budget Resolution (and recent appropriations activity.) We have not tried to model the overall effects on the Commonwealth of the efforts to balance the budget. Presumably, a balanced budget will lower interest rates and stimulate investment. We have not captured these beneficial effects or any additional shocks to the state that may come in the form of reduced federal spending in other areas. Under this scenario, we estimate that federal support of research spending in Massachusetts in the year 2002 would be 16% less than it was in 1995,[2] even before calculating for the effects of inflation. A policy scenario less extreme than the **declining spending** one holds federal research support in all categories at the same level, without adjustment for inflation, over the period 1995-2002. Of course, such a "constant spending" scenario would amount to continuous reductions in the "real" or inflation-adjusted level of support.

In order to quantify the impact of these reductions on the Massachusetts economy, one must postulate what the level of spending would have been under a business as usual or what we classify as our "baseline scenario." For the **baseline scenario**, we use current spending levels extrapolated into the future based on an existing economic forecast. This baseline forecast has civilian federal R&D growing slightly in real terms and defense-related R&D declining in real terms, resulting in an overall baseline forecast for federal research support in Massachusetts very close to a level that is constant after adjustment for inflation. In very broad terms, therefore, we pose the following question: *relative to a world in which overall federal support of research in Massachusetts roughly keeps pace with inflation, what is the impact of (1) significant cuts in nominal spending (**declining spending scenario**) or (2) spending that is constant in nominal terms and hence declining after adjustment for inflation(**constant spending scenario**).*

The impacts that are modeled in this report are the differences between these two policy scenarios and the baseline forecast.

- For the **declining spending scenario**, the difference relative to the baseline is the sum of two effects: the spending *decline* that occurs after 1995 under the declining spending plan; <u>and</u> the spending *increase* that is assumed to occur (roughly keeping pace with inflation) after 1995 in the baseline forecast. We estimate then that the combination of these two effects when compared to the baseline yields a 3% reduction in 1996, increasing to 35% in the year 2002. The

[2] This estimate is based on underlying estimates for spending by agency, combined with calculations taking into account the dependence of Massachusetts institutions on the funding of particular agencies. For more detail, see Section IV below and the Technical Appendix.

overall reduction of 35% in the year 2002 for the **declining spending scenario** consists of reductions of about 37% in the support of universities, hospitals and other non-profits and 34% in industrial research.

- For the **constant spending scenario**, there is no decline in spending, so the gap between that scenario and the baseline is the result of the increases in spending that are presumed to occur in the baseline. Overall this difference amounts to 23% in 2002, with the university/hospital sector experiencing a decrease of 27% and industry experiencing an overall decrease of 19%.

As discussed more fully in subsequent sections of this study, we quantify three effects of these spending reductions on the economy of Massachusetts.

- *First,* there is what we call the "direct" demand effect of the diminished flow of federal dollars into the state, in the form of reduced wages and the concomitant reduction in purchases of other goods.

- *Second,* there is what we call an "induced" demand effect, because economic research demonstrates that the R&D efforts of industrial firms are stimulated by the research activities of the non-profit sector; hence, the reductions in federal support of non-profit research will induce a reduction in industrial research.

- *Finally*, there is a "supply" effect, as the reduced research in both the non-profit and industrial sectors reduces the flow of new technology and hence the flow of new goods and services produced in the Commonwealth.[3]

Figure 1-1 provides a schematic overview of these different effects; further discussion of this model is provided in Section III below. To preview the results, Figure 1-2, provides a graphic representation of the magnitude of these different effects under the **declining spending scenario**. In the short run (1997-2002), the

[3] See Appendix B for a glossary of terms used in this report.

Figure 1-1

The Innovation System

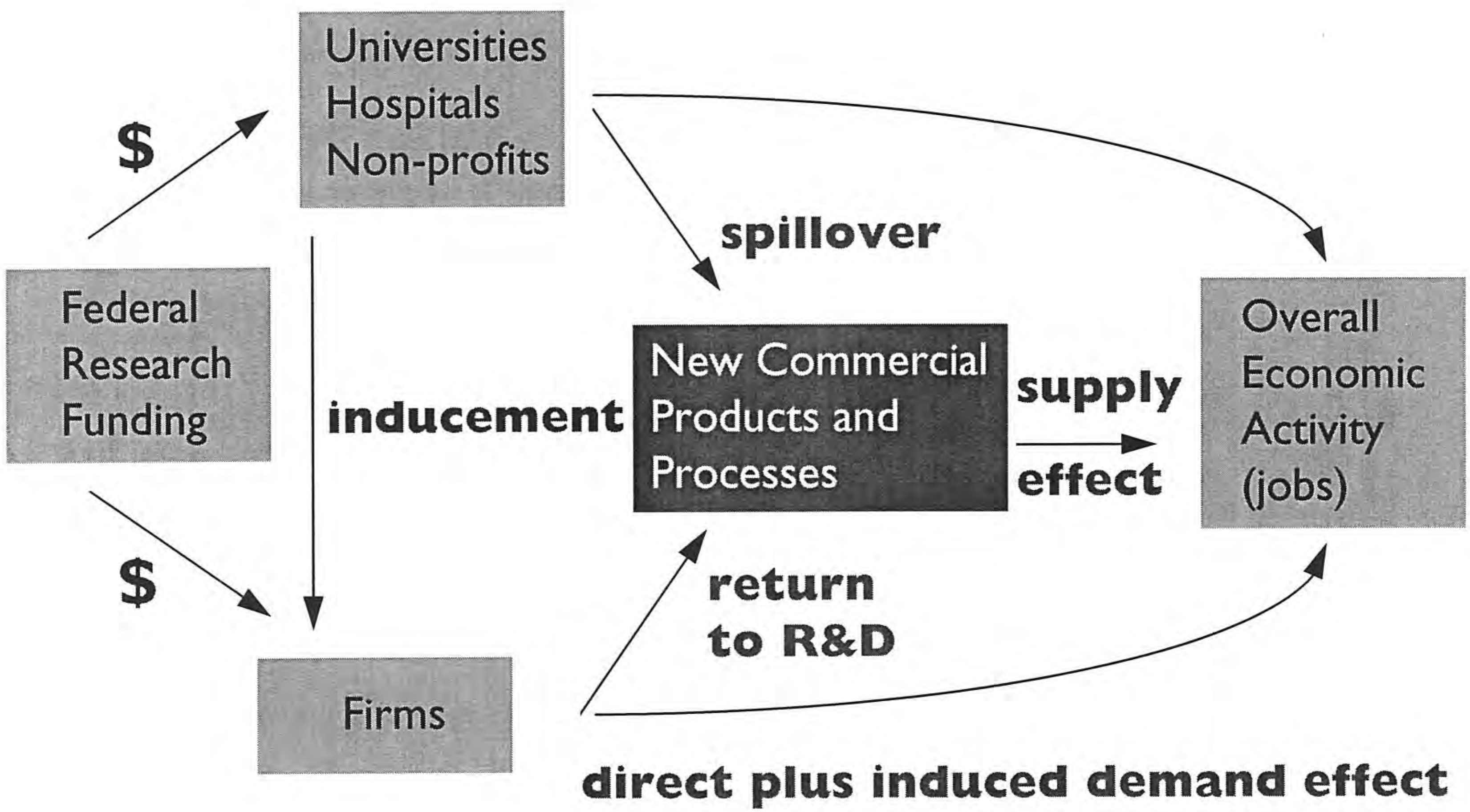
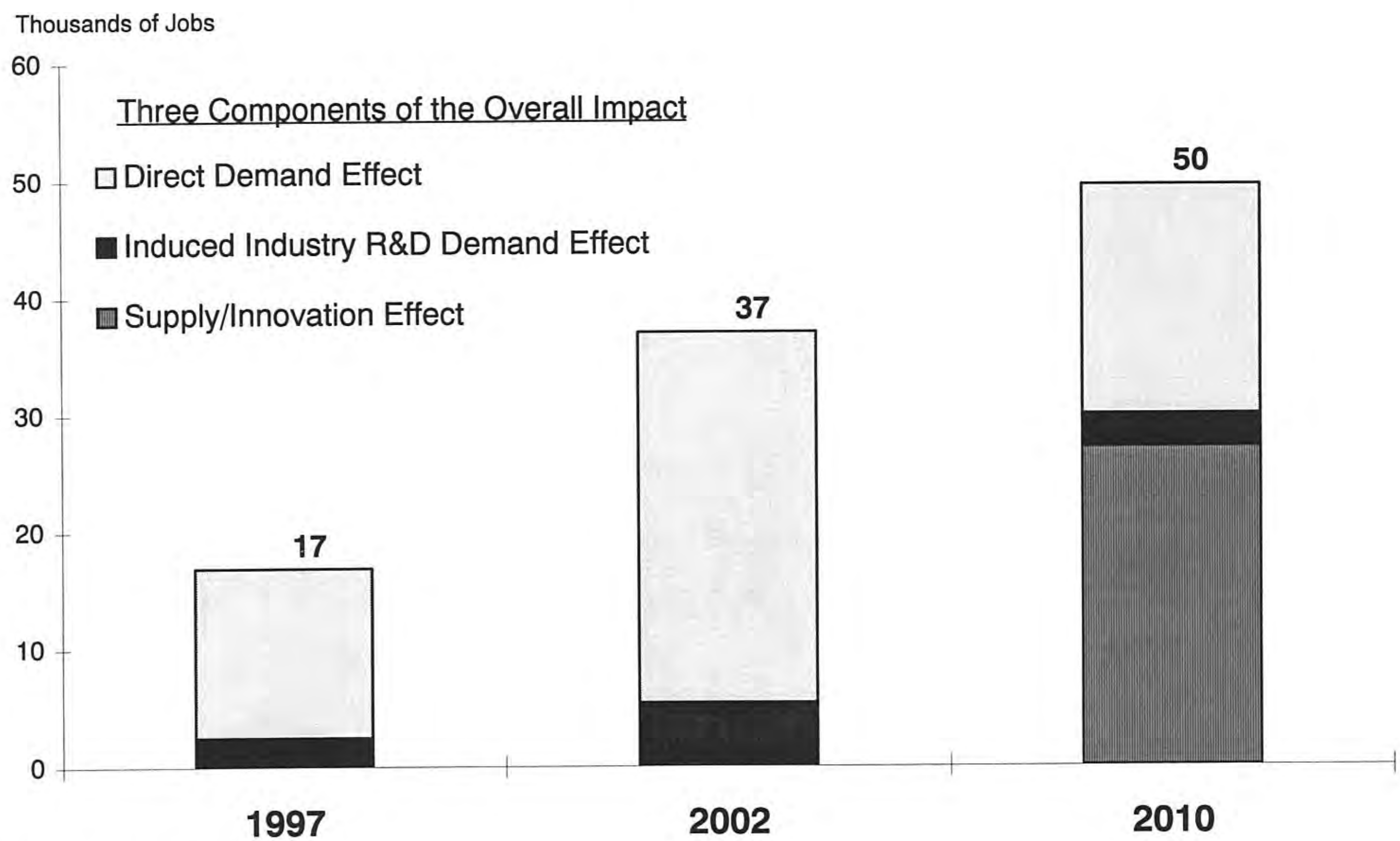


Figure 1-2
Impacts of Federal Research Cuts on the Massachusetts Economy:
Employment Reduction Relative to Baseline Forecast
Declining Spending Scenario



Source: ERG calculations using REMI model

impact is dominated by the direct demand effects, with some contribution from the induced demand effect. Eventually, however, the supply or innovation effect grows in importance, so that by the year 2010 it accounts for more than half of the impact.

It should be noted that there are important related issues for high-technology industries in Massachusetts that are not included in our estimates of overall economic impact. First, as documented in several previous reports,[4] reductions in defense spending have *already* had important impacts on Massachusetts industries. Our baseline scenario already incorporates a significant reduction in federal support for defense-related research. The impacts quantified in this report are those *over and above* the impacts of previous spending cuts.

Second, balancing the federal budget is likely to result in significant reductions in federal spending outside of research that have important consequences for research itself. Based on the current budget priorities, it appears unlikely that there will be significant cuts in defense procurement, relative to the decline in federal defense spending that is already built into the base case. In other areas, however, spending reductions in addition to the direct cuts in research that we have modeled could have significant impacts on the research enterprise. As discussed further below, cuts in or changes in the rules controlling government reimbursement for health care through Medicare and Medicaid are likely to induce further reductions in the research activities of hospitals, or, at the very least, greatly constrain the ability of these institutions to replace lost federal research support with other revenues. Although these effects are not incorporated explicitly in our overall economic modeling, they are discussed below in the context of our analysis of the impact of the new environment on specific sectors.

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[4] *Report on the Massachusetts Defense Industry and Technology Base, Task Force on Defense Industry and Technology*, August 13, 1992; *Report on the Massachusetts Defense Industry: Report Update, Task Force on Defense Industry*, March 1994.

II THE ROLE OF SCIENCE AND TECHNOLOGY IN THE MASSACHUSETTS ECONOMY

Colleges and universities, hospitals, research institutes and high-technology firms of many types collectively play a large role in the economy of Massachusetts. In this section, we identify these important sectors, describe the scale of their research efforts, and identify the major sources of the funding for that research.

II.A Research-intensive sectors in the Massachusetts economy

Academic research institutions and research-intensive firms are important pillars in the foundation of long-term economic growth and employment in the Commonwealth, producing skilled graduates, new scientific and technological knowledge and commercial innovations essential to the comparative advantage of Massachusetts. These industries provide high wage, high productivity jobs and have allowed the state's economy to continue to grow, even as employment in manufacturing industries has decreased. A recent MTC report suggests that the strongest opportunities for employment growth will come from a new class of technology-intensive industries -- including software firms, communications networking companies, medical device manufacturers, and contract and research testing labs.[5] Prior studies on the Massachusetts economy have demonstrated that much of the competitive advantage of the Commonwealth lies in its technology-intensive industries. Studies by Michael Porter and his collaborators identified major industry clusters at the heart of economic growth in Massachusetts, including health care, information technology, knowledge creation, and financial services.[6] Most of these industries are highly dependent on a strong science and technology base.

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[5] *Technology and Economic Growth: The Structure and Performance of Technology-Intensive Industries*, Massachusetts Technology Collaborative and Nexus Associates, 1995, at 22.

[6] *The Competitive Advantage of Massachusetts,* 1991 and *Choosing to Compete*, 1993.

In this report, we focus on the R&D-intensive sectors that constitute the research infrastructure of the Commonwealth, as summarized in Figure 2-1. This industry categorization is constructed from National Science Foundation (NSF) R&D statistics, and hence differs somewhat from the sectors identified above and other definitions of "high technology" industries. There is, however, significant overlap with the knowledge creation, health care and information technology clusters identified by Professor Porter. In the aggregate, these sectors perform over 90% of total research in the Commonwealth. For most of our analysis we will distinguish what can be broadly labeled the "non-profit" research sector (including universities, hospitals, and other non-profit research laboratories) from the for-profit research sector principally-comprised of firms in high-technology industries.

In the non-profit sector, universities and colleges, hospitals, and other non-profit organizations are both major performers of research and key employers. Approximately 120 Massachusetts colleges and universities employ over 70,000 people, nearly 3% of total Massachusetts employment. In 1993, thirty-one of these institutions performed $770 million in federally funded research. Hospitals and associated medical laboratories are also significant employers and performers of research. In 1993, for example, it is estimated that hospitals conducted over $600 million in research, sponsored by both the federal government and by industry and other sources. Other non-profit research organizations such as Draper Laboratory, MIT-affiliated Lincoln Laboratory, and MITRE Corporation conduct research, much of it financed by the federal government.[7]

In the for-profit sector, most of the industrial R&D in Massachusetts is performed in several key industries: chemicals and drugs; computer equipment; electronic components and communication equipment; aerospace (including guided missiles); and professional and scientific instruments. Although these industries represent only about 6% of total employment, they account for 70% of the industrial R&D in the Commonwealth. Thus, along with the non-profit research sector, these

[7] For the purpose of the economic impact analysis, the non-profit research institutions other than hospitals (plus Lincoln Laboratory) are grouped together with the private firms in the Engineering and Research Services sector.

Figure 2-1
R&D-Intensive Sectors in Massachusetts

Industry	1994 Employment (000s)	% of Private Sector Employment	1993 Total R&D Expenditures (millions)*
Computer Equipment	28.1	1.1%	$2,095
Engineering and Research Services	98.7	3.9%	1,964 **
Colleges and Universities	70.9	2.8%	1,076
Communication Equipment	15.8	0.6%	876
Electronic Components	25.4	1.0%	680
Hospitals & Other Medical Research Institutions	133.3	5.3%	628
Aircraft & Missiles	18.3	0.7%	568
Optical, Surgical, Photographic and Other Instruments	24.8	1.0%	294
Measuring Instruments	22.5	0.9%	230
Chemicals and Allied Products (excluding Drugs)	13.0	0.5%	204
Drugs	4.9	0.2%	57
Total	455.7	18.1%	$8,673

*ERG estimates for 1993 from latest available data
**Includes non-manufacturing industrial R&D, Lincoln Labs, and non-medical, not-for-profit research institutes.

Source: NSF, Mass Dept. of Employment and Training.

industries are the locus of technological innovation and technology-driven economic growth for the Commonwealth.

II.B Composition and sources of research spending

Figure 2-2 provides an overall summary of performers and sources of funds for research in Massachusetts. Research expenditures in Massachusetts are large in overall scale and in importance to the state economy. In 1993, $9.6 billion was spent on research and development in all types of organizations in Massachusetts, nearly 6% of Gross State Product (GSP).[8] The majority of research activity in Massachusetts takes place in firms, with industrial R&D accounting for nearly 72% of the total, while academic institutions and nonprofit organizations account for about 23% of the research spending in Massachusetts.

Federal funding. Federally funded research and development is an important component of Massachusetts R&D. (The specific sources of federally funded R&D vary by institution and will be discussed below.) According to NSF surveys, 43% of the total research and 72% of academic research in the Commonwealth is funded by the federal government. For industrial firms, the federal government funds about 27% of total research efforts. Figure 2-3 dramatizes the importance of federal funding in Massachusetts. Massachusetts is much more dependent on federal funding than the U.S. as whole. This is true overall and in both the academic and industrial sectors. The two most important sources of federal support in Massachusetts are the Department of Defense and the Department of Health and Human Services (HHS) (primarily the National Institutes of Health). Because of the importance of federal funding to the Massachusetts R&D base, the imminent cutbacks in federally funded research will have an especially negative impact on the Commonwealth.

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[8] R&D expenditures are measured by surveys done by the NSF of universities and other non-profit institutions and industrial firms. Gross state product is the total "value-added" (sales minus intermediate purchases) generated within the Commonwealth; it corresponds to Gross Domestic Product (GDP) measured at the national level.

Figure 2-2

Summary of 1993 R&D Spending by Funding Source for Massachusetts

(Millions of Dollars)

	Source of Funds		
R&D Performer	Total	Federal	Other
Industrial R&D	6,952	1,878	5,074
Academic R&D	1,076	770	306
Other Non-Profit R&D*			
Hospitals and Medical Research Institutes	628	502	126 ***
Other Research Institutes**	554	554	
Federal Intramural	384	384	
Total R&D Funding	$9,594	4,088	5,506

* Breakdown of non-profit institutions by type not available from NSF.
ERG estimates are based on obligations data.

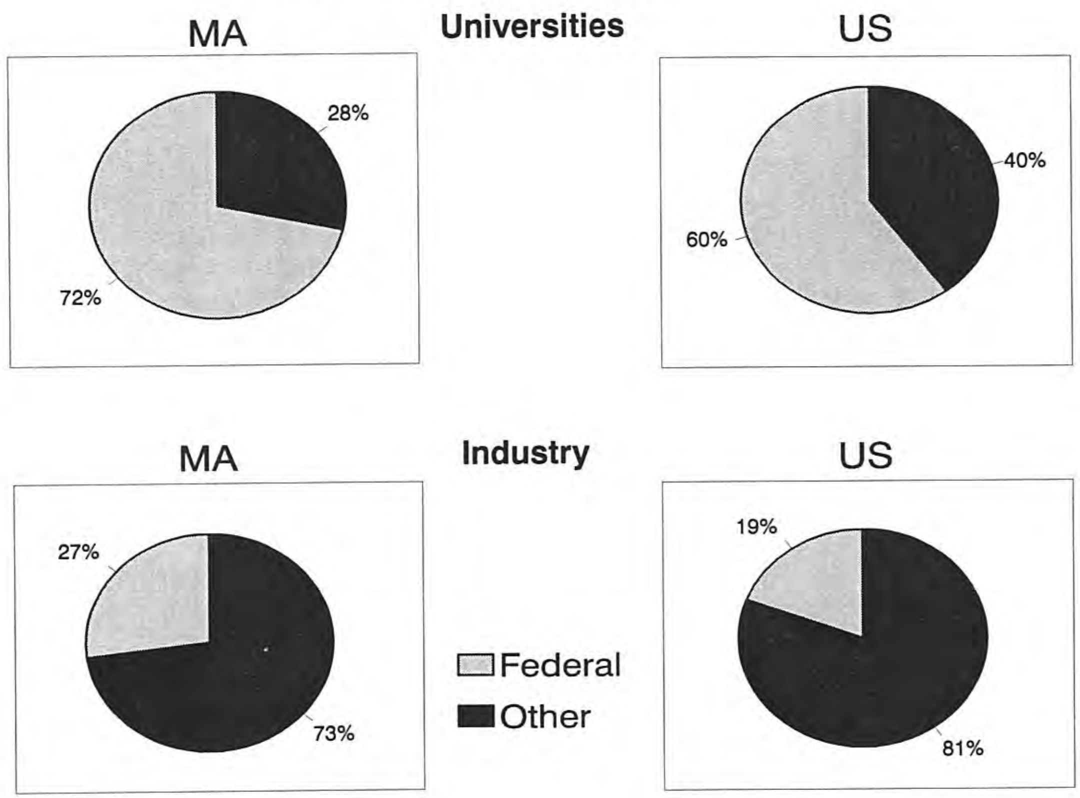
** Includes MIT Lincoln Laboratories, Draper Laboratory, MITRE, and non-medical research institutes.

*** ERG estimate

Source: NSF; ERG estimates.

Figure 2-3

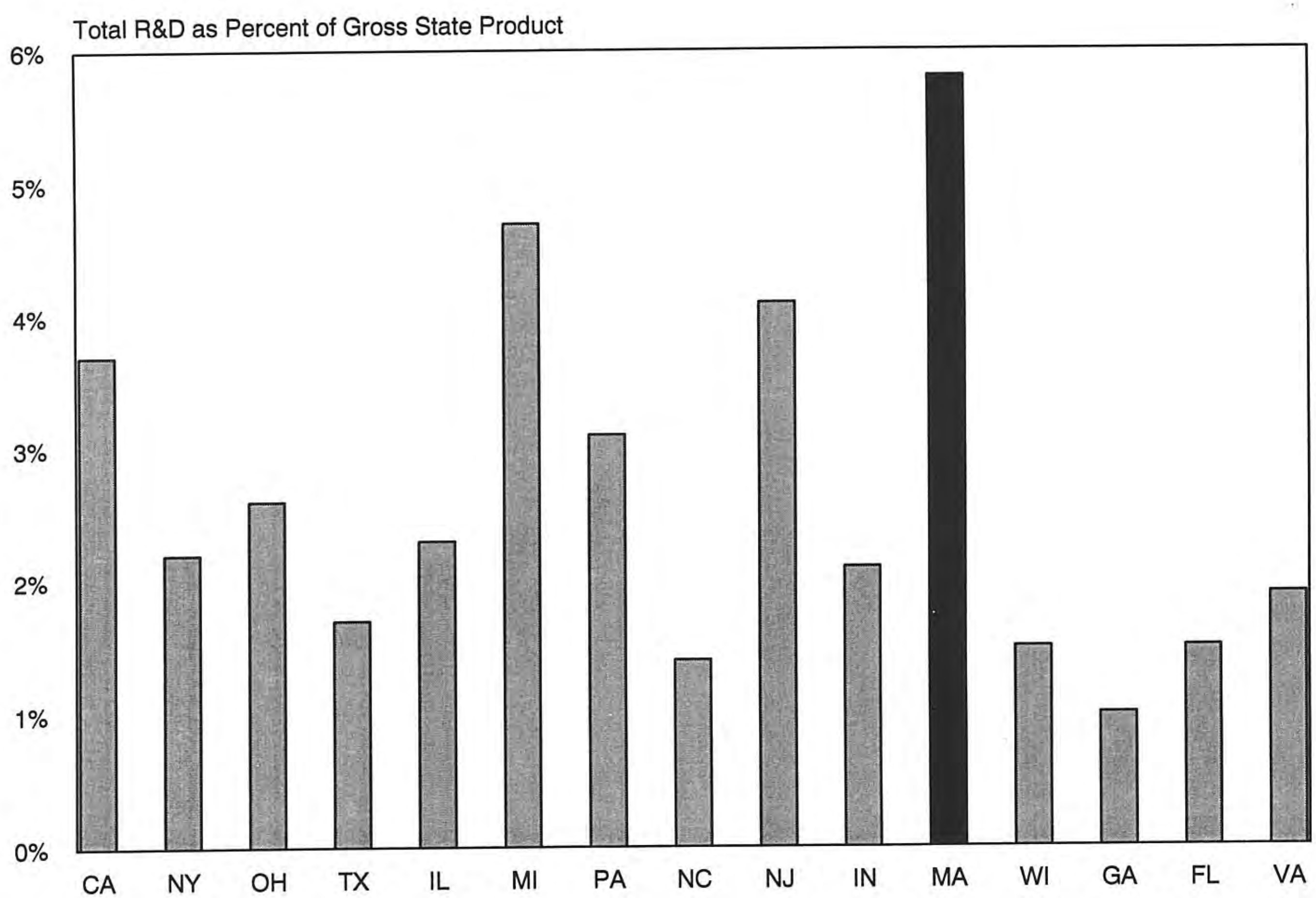
Importance of Federal Research Support in Massachusetts and U.S.



Source: NSF

Figure 2-4

Research Intensity in Largest Manufacturing States



Source: NSF

approach this analysis to aid policymakers charting their options for the cutback in research funding.

II.C Research institutions

This section provides more detail about the principal institutions within the Commonwealth that perform research. We can provide a thorough picture of the research activity of specific universities and other non-profit organizations since data is available by institution. For industrial R&D, an important component of overall R&D, we have less detailed information available, although NSF surveys provide aggregate information which permit the development of a broad brush picture of the composition of industrial R&D.

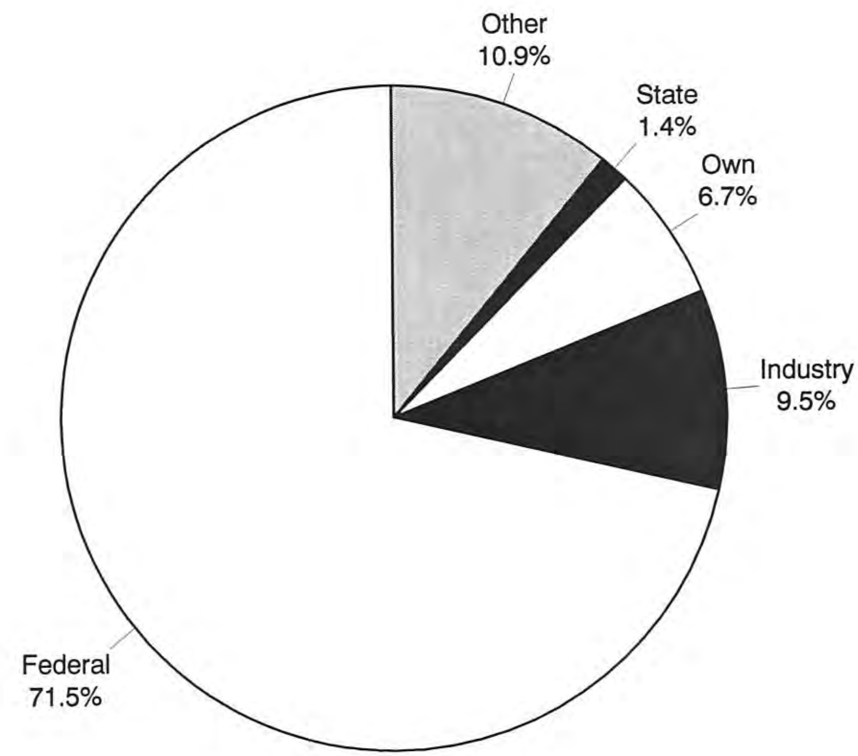
Universities. Figure 2-5 examines the sources of research funding at Massachusetts universities and colleges. Collectively, these institutions performed over $1 billion of research in 1993. Overall, most academic institutions in Massachusetts are heavily dependent on federally funded research, receiving over $700 million dollars from the federal government in 1993. In contrast, state and local sources of funding to Massachusetts universities amounted to only $15.6 million dollars (or about 1.5% of all 1993 funding), with about two-thirds of this allocated to the University of Massachusetts campuses. University research is also funded by industry (about 9.5% of funding), by universities' own funds (6.7%), and from other sources including foundations and private donations (10.9%).

Academic institutions in the Commonwealth do quite well relative to similar institutions in the rest of the U.S. in soliciting R&D funds from industry. In 1993, for example, industry provided 7% of all R&D funding at universities nationwide, but 9.5% of total university funding in the Commonwealth. Individually, MIT attracted $58 million in industry funding in 1993, more than 15% of its total R&D budget. At the University of Massachusetts at Lowell, industry funding represented 25% of all research expenditures for the campus. (See Technical Appendix for the breakdown of funding for individual universities.)

Figure 2-6 represents research funding by source at Massachusetts universities over the last two decades. Driven primarily by significant increases in federal support, the overall level of research funding rose strongly during the 1980s,

Figure 2-5

Sources of Research Funding at Massachusetts Universities
1993

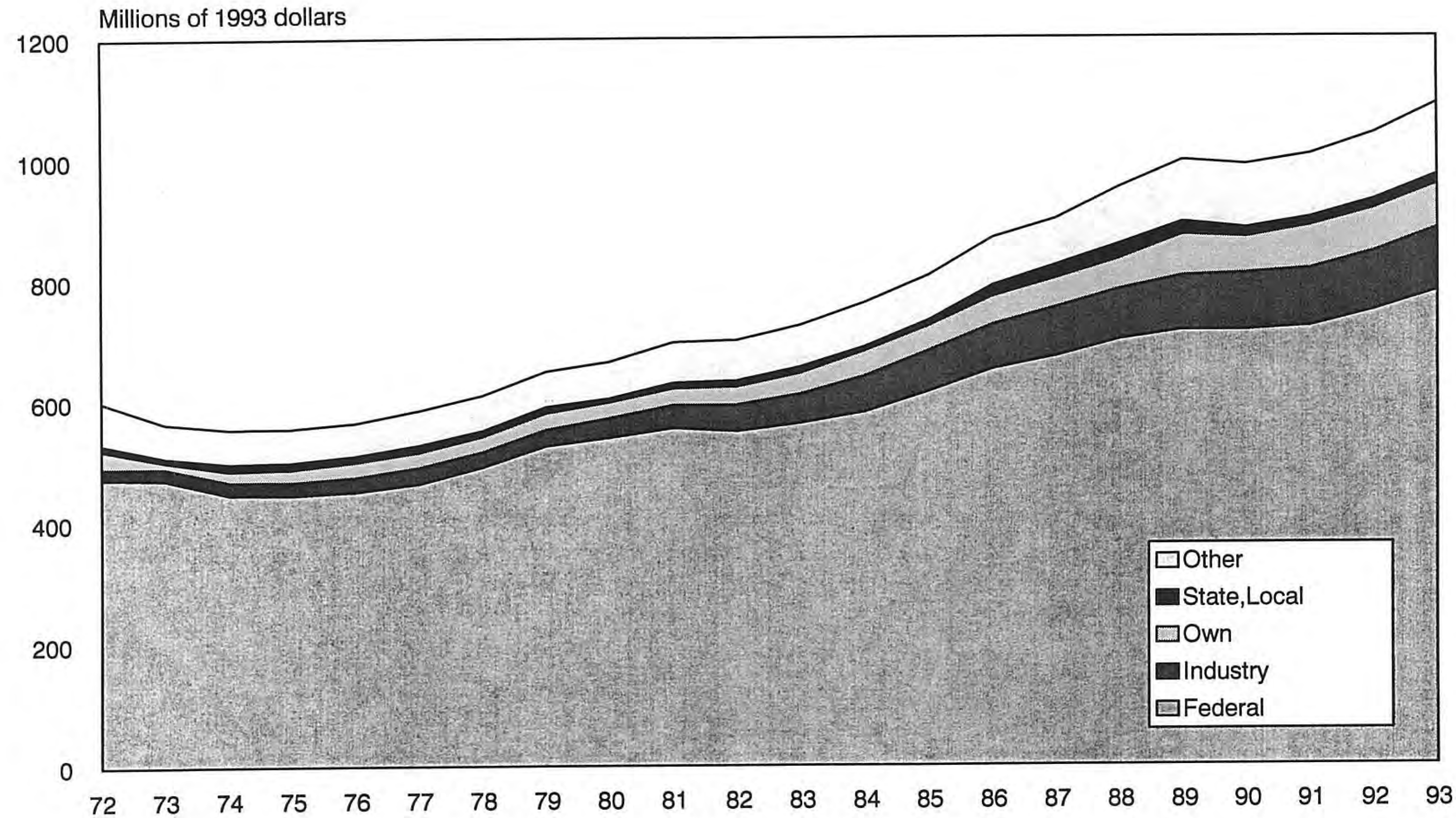


Source: NSF

Figure 2-6

R&D Funding by Source for Massachusetts Universities

1972-1993



Source: CASPAR/NSF

even after adjustment for inflation. In more recent years, federal funding has increased less rapidly than industry and own-institution funding. From this perspective, we observe that the federal reductions now contemplated will return academic research to levels of support which existed in the mid 1980s.

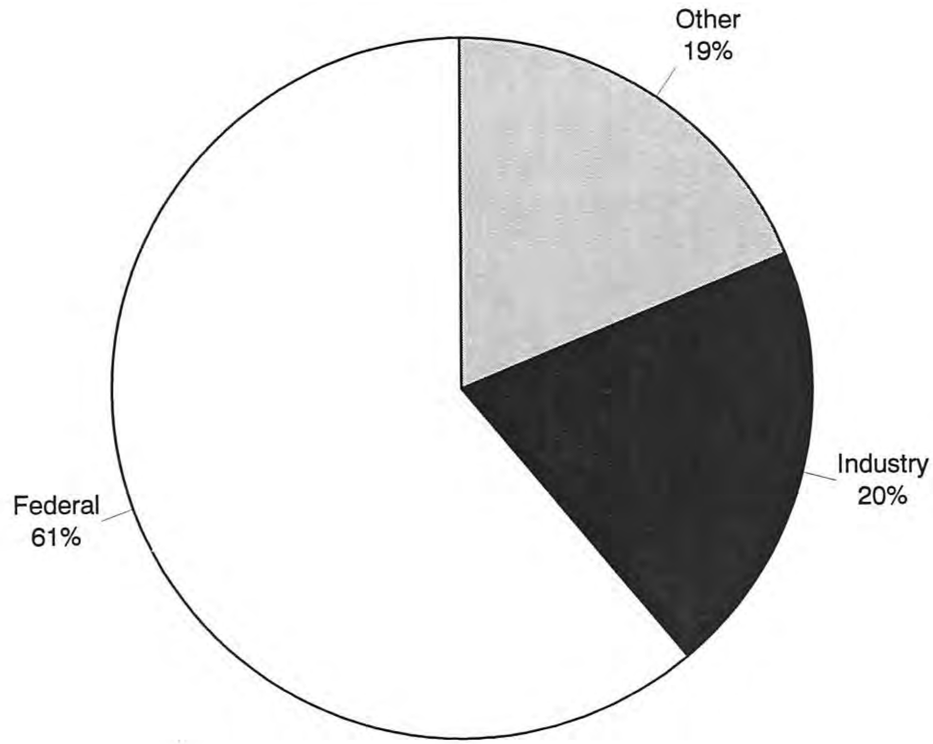
Hospitals and other non-profits. The hospital sector in Massachusetts is among the largest in the U.S. Massachusetts non-profit hospitals receive more research support from the National Institutes of Health than those of any other state. Six of the ten hospitals that receive the greatest amount of federal research funding are located in the Commonwealth.

Massachusetts is also home to other research institutes that perform medically related research, such as the Center for Blood Research and the Forsyth Dental Center. Other non-profit institutions in Massachusetts include MITRE Corporation and Draper Laboratories, research laboratories funded by the Department of Defense and NASA, as well as one Federally Funded Research and Development Center (FFRDC) -- Lincoln Laboratory, operated by MIT and funded by the Air Force. In 1993, Lincoln Laboratory received $355 million in funding, all from the Department of Defense.

NSF does not provide information on non-federal research funding at non-profit institutions, which would include expenditures by hospitals of their own funds in support of research. Based on a survey by the Association of University Technology Managers (AUTM), industry-sponsored research expenditures at the six Massachusetts hospitals that responded to the AUTM survey ranged from 16% of total sponsored research at Brigham and Women's Hospital to 44% at New England Deaconess. These funds are typically earmarked for clinical studies. Other external sources of support, which include foundations, other philanthropic organizations, as well as endowments dedicated to specific areas of research, range from 0% to 43% at the institutions in the AUTM survey. Figure 2-7 illustrates the breakdown of research funding by source at the largest hospitals in Massachusetts. Not included in this amount are funds hospitals are typically forced to expend to cover indirect costs associated with research that are not fully recovered through the sponsored funding. While the amount varies across institutions, it has been estimated by one research director that sponsored research only covers about 92% of the total costs associated with conducting such research.

Figure 2-7

Sources of Research Funding at Massachusetts Hospitals
1993



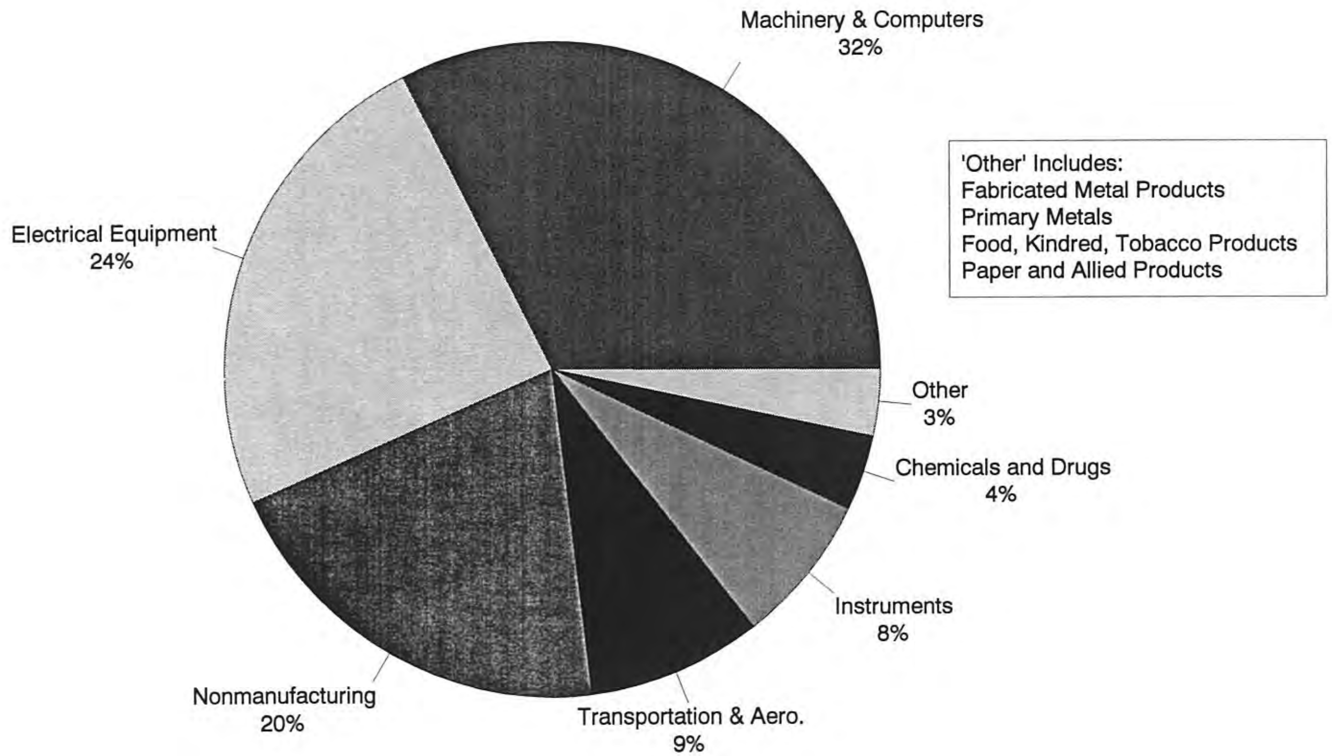
Note: the following hospitals are represented: Massachusetts General, Brigham & Women's, Dana-Farber Cancer Institute, Children's Hospital (Boston), New England Medical Center, Beth Israel Hospital, and New England Deaconess Hospital.

Source: AUTM

Firms. Industrial R&D in Massachusetts amounted to nearly $7 billion in 1993. Figure 2-8 describes the breakdown of research across industries for 1991, the most recent year for which such detailed data is available. The largest generators of industrial R&D are machinery and computers; electrical and electronic equipment; transportation and aerospace; scientific instruments; and chemicals and drugs. Note that for nonmanufacturing industries the NSF does not break out the research by industry. Nonmanufacturing industries include research and test laboratories and engineering services. As reflected in Figure 2-9, these industries vary dramatically in their dependence on federal support. The electrical equipment, transportation, and nonmanufacturing sectors are quite dependent on federal funding. For firms in these industries reductions in federal research support will have a compound impact, with decreases in both their own funding and also that of non-profit institutions upon which they depend for research and innovation.

Figure 2-8

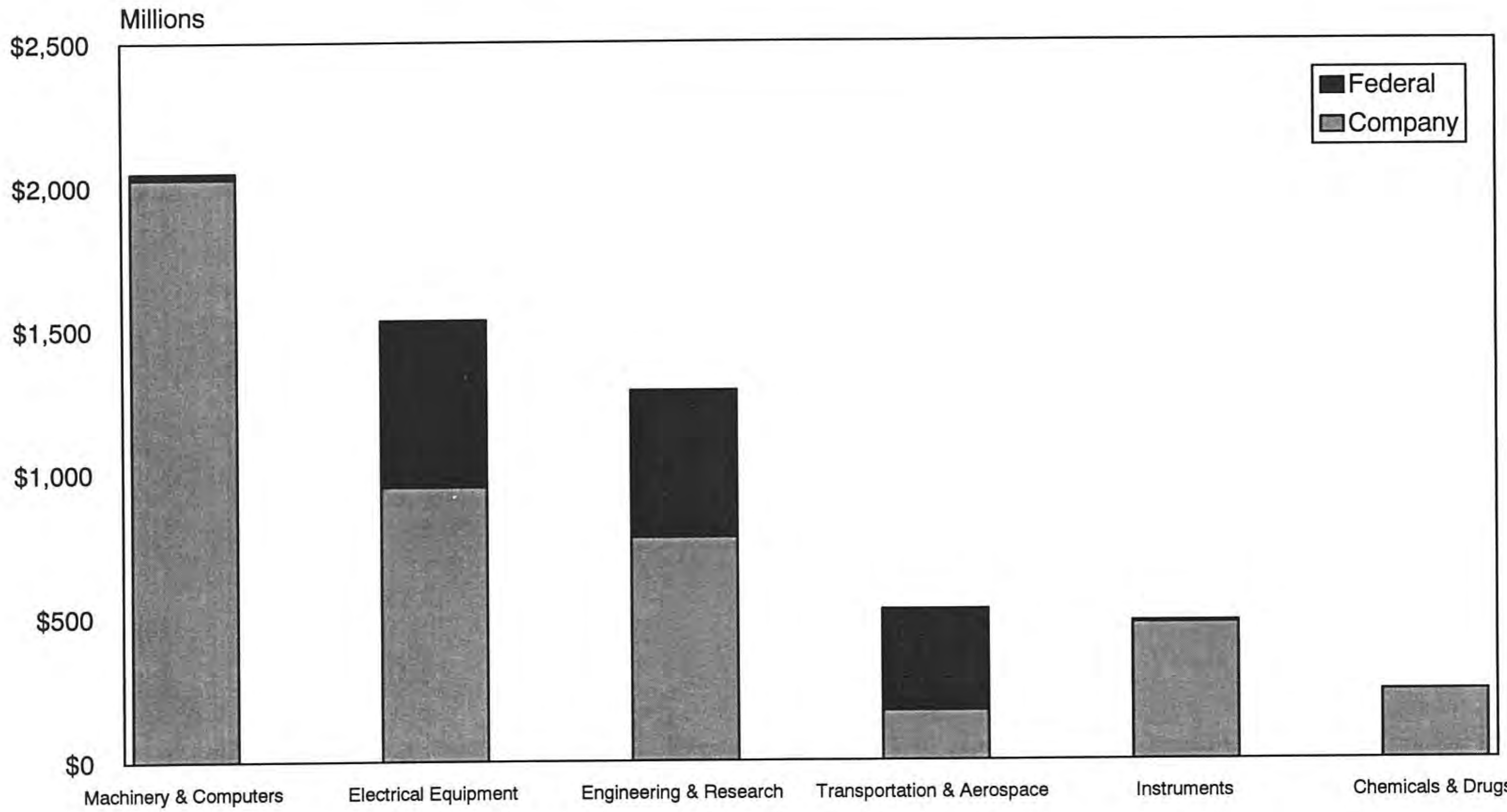
Composition of Industry R&D in Massachusetts
1991



Source: NSF

Figure 2-9

Massachusetts Industrial R&D by Source of Funds
1991



Source: NSF

III PATHWAYS AND MECHANISMS FOR ECONOMIC IMPACT OF RESEARCH

III.A Overview of pathways of economic impact of research cuts

The level of external funding of research activity within the Commonwealth affects the level of economic activity through several direct and indirect mechanisms. These pathways are summarized in Figure 1-1. The direct, short-run effect is that research funding is used to pay employees and purchase supplies and equipment; reductions in funding translate into reductions in wages and purchases. These reductions in wages and purchases have further "ripple" effects through the local economy, creating a "multiplier" effect that is standard in modeling the regional economic impact of spending changes. In this report, we analyze this direct economic impact with respect to cuts in federal support of research both in the non-profit sector and in the for-profit firms. With respect to these effects, reductions in federal funding of research in Massachusetts have effects that are qualitatively similar to the effects of reductions in any other form of federal spending.

What makes research spending different is that research activities, particularly in the non-profit sector, generate "spillovers." The nature of these spillovers and the mechanisms by which they flow will be discussed in more detail below, but at the overview level it is sufficient to think of research at universities, hospitals and other non-profits as generating new technology, which leads (usually after additional research and development effort in the for-profit sector) to new commercial products or processes. The economic consequence of these spillovers can be broken into two components. First, because firms undertake R&D of their own in order to capture and exploit the spillovers from the non-profit sector, a reduction in non-profit R&D induces a reduction in industrial R&D, over and above the reduction in direct federal support of industrial research.[12] We call this the "inducement" effect. Because the overall scale of R&D in industry is much larger than in the non-profit sector, this inducement effect can be large. This induced

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[12] Adam Jaffe, "Real Effects of Academic Research" *American Economic Review*, December 1989.

reduction in industry R&D has a multiplier effect just like the reduction in federally supported R&D; thus the arrow in Figure 1-1 labeled "direct plus induced demand effect" captures the combined multiplier effect of reductions in industry R&D due to reductions in *federal* industry support, and the indirect or induced reduction in industry R&D due to reductions in federal support of non-profit research.

In addition to generating this secondary or induced demand-side effect, the reduction in university research, combined with the induced reduction in industry research, has an effect on the supply-side of the economy. Fewer new products and processes are introduced, slowing the growth in sales of the affected industries. This supply effect will, in general, take much longer to manifest itself than the demand-side effects. However, it will also last much longer. That is, the reduction in demand generated by the reduction in spending on wages and supplies (including the "multiplier" effect) in both the non-profit and for-profit sectors will affect the local economy almost immediately, but this effect will be significant only for as long as reductions continue. A reduction in the introduction of new products and processes, on the other hand, will take much longer to have any impact, but the loss of new products and processes will continue to inhibit the growth of the affected industries even if funding levels were to recover.

In order to quantify the impact on the Massachusetts economy of potential cuts in research funding, we need quantitative measures of the extent of the inducement and spillover effects, and also measures of the distribution of these impacts across industrial sectors. We have utilized estimates from published economic literature on the magnitude of these effects, but there are no published estimates that we could use showing how these impacts would be distributed across industrial sectors. In order to fill this gap, we undertook a comprehensive analysis of the patents received by universities, hospitals and other non-profits in Massachusetts, and the citations or references made by patents taken out by private firms to these non-profit-sector patents. *We use the citation pattern as a proxy for the industrial distribution of the spillover effects of non-profit research.* This analysis tells us that, for hospitals, other non-profits, and universities, the distribution of spillover impacts cuts across industrial sectors. For university patents, we distinguish broad fields of science and engineering that correspond to NSF funding data.

The complete results of this analysis are described in the Technical Appendix, but Figure 3-1 illustrates the kind of data that we have developed. It shows, for hospitals, Lincoln Laboratory and for two university departments (Engineering and Math/Computer Science), how the industrial citation of the output of these enterprises is distributed across industries. Of all of the citations made by firms to patents taken out by Massachusetts hospitals, 49% came from firms in the chemical industry, including drugs. Another 21% came from instrument firms and 12% came from engineering and research firms. In contrast, citations to Lincoln Laboratory patents come primarily from the machinery and computers, electric and electronic equipment and transportation and aerospace sectors. Engineering departments, not surprisingly, have a broad impact across many different sectors. Much of the impact of Math/Computer Science departments is in the computer industry, but there is also significant impact in electrical equipment and transportation/aerospace.

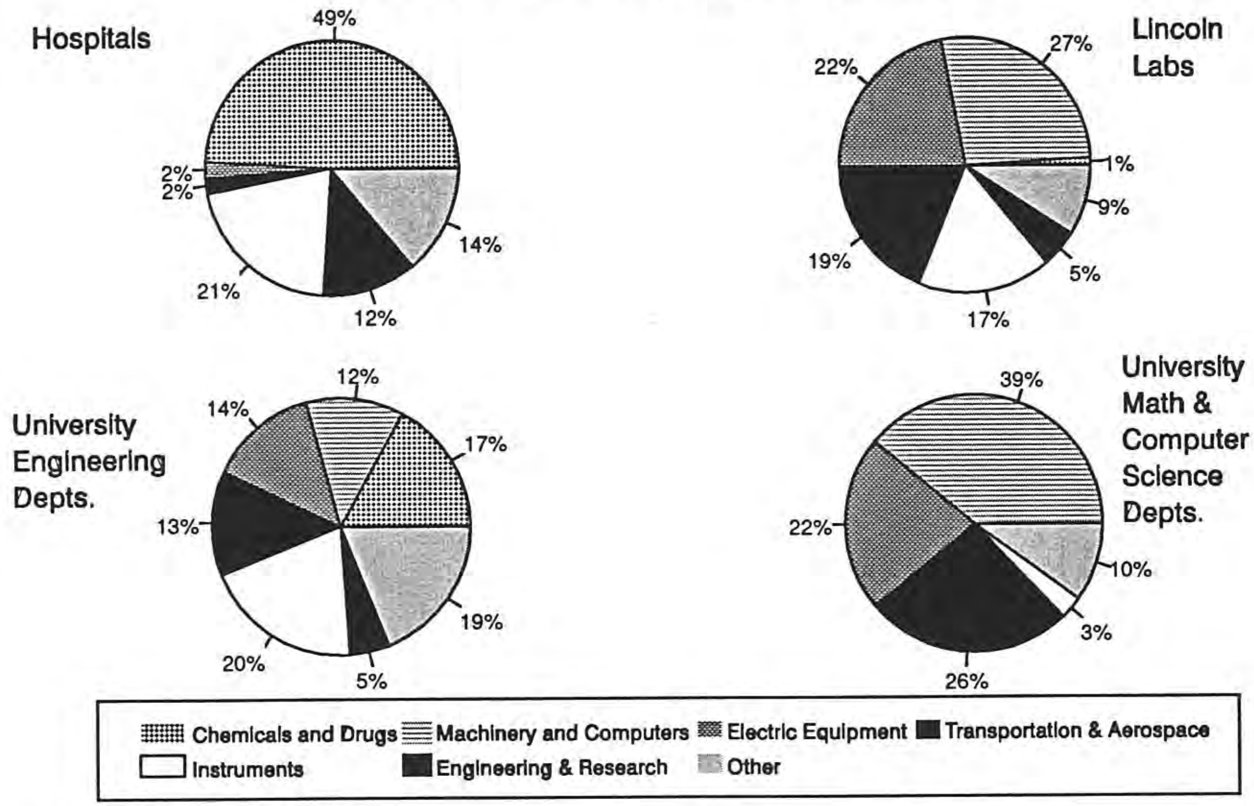
An important question in this analysis is the extent to which the spillover and related inducement effects of non-profit research are localized within Massachusetts. Although the ability to codify and communicate new knowledge via many media causes much of the impact of new technology to be nation-wide or even world-wide, there is much evidence that tacit knowledge and the greater effectiveness of face-to-face communication cause a significant fraction of the spillovers to occur near the research institution. We return to this issue below.

III.B Evidence on spillover pathways of university and other non-profit research

In section IV of this report, we use statistical estimates of the magnitude of spillover effects to model quantitatively the economic effects of cuts in research activity. This statistical estimate is a "reduced form" estimate or summary of the overall effect, rather than a description of a particular spillover mechanism. Without trying quantitatively to estimate the contribution from various components, this section discusses the kinds of mechanisms that contribute to the generation of spillovers and examines some of the specific institutions in Massachusetts that facilitate the transfer of research from the university and non-profit setting to industrial firms.

Figure 3-1

Estimated Spillover Impacts Across Industries
(Selected Components of the Non-Profit Sector)



Source: ERG analysis of USPTO data.

These mechanisms and institutions are listed in Figure 3-2. Clearly, some of these pathways have more impact on the state's economy than others. For example, explicit technology transfer through universities and hospitals and joint research centers have a larger impact than incubators and industry councils in terms of economic activity generated. However, there is some tradeoff between scale and the likelihood of localization; while industry councils and incubators are likely to generate less activity, the spillovers from these activities are more likely to be located with the state. The rest of this section provides examples of how different spillover pathways operate in Massachusetts.

Licensing: Explicit technology transfer is an important pathway for spillovers from the non-profit sector to the for-profit sector. Through licensing offices, firms license technology developed in a non-profit setting and invest resources to create a commercial product. A recent study by Pressman *et al.* found that the investment made by firms before production was quite significant. On average, companies invested $5.5 million to convert a technology licensed from the Massachusetts Institute of Technology into a new product or improved process.[13] This kind of investment is an example of the "inducement" effect described above, whereby private firms invest research resources in order to exploit or build upon research results from the non-profit sector.

Massachusetts universities and hospitals expend significant resources to transfer potential commercial technologies generated by their research to private sector firms. Figure 3-3 provides a summary of the scale of the licensing effort at selected individual Massachusetts institutions and measures the number of invention disclosures, patent applications, and active licenses. In 1993, the latest year for which such information is available, these institutions filed 580 patent applications and generated 270 new licenses and options; altogether they had almost 900 active licenses and options. At the larger institutions there is typically a significant licensing office, with approximately two full-time equivalent employees

[13] Lori Pressman *et al.* "Pre-Production and Jobs Induced by MIT Exclusive Patent Licenses: A Preliminary Model to Measure the Economic Impact of University Licensing," MIT Technology Licensing Office, 1995. The study found that "start-up" companies invested an average of $23 million in pre-production investment.

Figure 3-2

Spillover Pathways

- Explicit technology transfer
- Startup of new firms
- Industry-funded university research centers
- Joint industry/university research centers
- Consulting
- Graduates
- Incubators, technology parks, other public/private ventures
- Industry councils, partnerships, networks, collaboratives

Figure 3-3
University and Hospital Licensing Offices

Name of Institution	FY 1993 Total Sponsored Research Expenditures	FY 1993 Professional FTEs for Licensing	FY 1993 Invention Disclosures Received	FY 1993 U.S. Patent Applications Filed	FY 1993 Licenses & Options Executed	FY 1993 Total Active Licenses & Options	FY 1993 Royalties Received
Massachusetts Institute of Technology *	$361,400,000	8.80	282	161	71	322	$5,808,000
Harvard University	$319,800,000	7.50	97	91	53	202	$5,430,000
Massachusetts General Hospital	$166,004,023	3.50	108	124	35	82	$1,125,498
Brigham & Women's Hospital	$122,591,306	3.00	55	42	22	52	$1,331,351
Dana-Farber Cancer Institute	$86,303,000	2.75	54	54	19	66	$2,847,172
Woods Hole Oceanographic Inst.	$73,300,000	0.50	3	3	4	10	$15,000
Children's Hospital, Boston	$60,000,000	1.50	54	40	7	33	$1,290,000
Univ. of Massachusetts Medical Center	$52,079,348	0.50	23	13	3	23	$168,179
New England Medical Center	$44,400,000	1.50	15	15	8	23	$393,000
Brandeis University	$35,000,000	0.25	14	1	9	26	$100,000
New England Deaconess Hospital	$24,116,000	0.50	4	8	0	7	$62,259
Northeastern University	$20,815,000	0.25	28	23	9	9	$60,000
TOTAL	**$1,365,808,677**	**30.75**	**747**	**580**	**270**	**887**	**$18,633,159**

* Includes Lincoln Laboratories.

Source: AUTM Licensing Survey.

for every $100 million in sponsored research expenditures. Within the past year, UMASS has overhauled its technology transfer policies, established an Office of Commercial Ventures and Intellectual Property (CVIP), and set up its first patent fund. The UMASS Medical Center has a fully functioning CVIP operation, while the Amherst and Lowell campuses are currently recruiting technology transfer officers. Smaller institutions have developed a variety of means for organizing technology licensing. For example, the Unified Office of Technology Transfer (UOTT), under the direction of the Massachusetts Biotechnology Research Institute, serves as the collective licensing office for eight Massachusetts institutions.[14] Formed in 1992, UOTT allows the members to pool resources by providing one centralized agent for the negotiation of technology licensing agreements for the respective institutions.

Of course, not all the licenses from Massachusetts institutions are granted to Massachusetts firms. However, the proximity of the research programs at universities and firms makes it logical that local firms should benefit more than proportionally from local research. We examined licensing patterns from two institutions -- MIT and Massachusetts General Hospital. Of all MIT licensees, 38% were Massachusetts companies, while at Massachusetts General Hospital 29% were.[15] Since these two institutions employ a relatively large number of licensing professionals, we expect their portfolio of licenses to be quite diverse. Thus, evidence that about a third of the licenses are with local companies provides powerful evidence that spillover effects are disproportionately localized.

Start up of new firms: In many cases, new firms are started around technology licenses from academic research. Given that such start-ups often have close ties to faculty and scientists located at the respective research institutions, they are more likely to be located within the state than existing companies that might license new technologies developed at such institutions. In the case of MIT,

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[14] This includes: Boston Biomedical Research Institute, Clark University, College of the Holy Cross, St. Elizabeth's Medical Center, The Medical Center of Central Massachusetts, Tufts University, Worcester Polytechnic Institute, and Worcester State College.

[15] The lower localization ratio for MGH may reflect the fact that the drug industry, which relies heavily on hospital research (Figure 3-1), is not particularly strong in Massachusetts.

for example, over 60% of its start-up licensees are located in Massachusetts. Further, start-ups are likely to have a larger economic impact than established firms. The MIT study found that start-ups spend more, on average, in developing the new technology than do established firms: an average of over $2 million per year, compared to less than a half-million per year for established firms (Pressman, *et al.*, Table 8). Once the technology gets to the production stage, start-ups may be more likely than other firms to locate production operations within the state, both because they do not have existing manufacturing plants elsewhere and because of their desire to maintain close ties between technical and production operations. Thus, the start-up of new firms is likely to be one of the most important overall mechanisms by which academic research creates spillover benefits within the Commonwealth.[16]

Joint industry university centers: Such centers bring together industry and universities as partners in the research and development of new products and processes. Massachusetts universities have been quite successful in establishing programs and consortia designed to meet the needs of industry through focused research efforts. MIT, for example, offers many research consortia including the Biotechnology Process Engineering Center and the Consortium for Superconducting Electronics. In return for a fee paid to the respective center, corporations receive such benefits as early access to research results, participation in symposia, and non-exclusive commercial rights to patents or copyrights resulting from research undertaken under the auspices of the consortia.

Another example of industry-university partnership is the Center for Intelligent Information Retrieval (CIIR), affiliated with the computer science department of the University of Massachusetts at Amherst. Companies (from within Massachusetts and from other states) are members, contributing both funding and research staff. Graduate students move between the center and affiliated companies. While the basic research is undertaken by graduate students,

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[16] The Governor's Council on Economic Growth and Technology Task Force on Financing Emerging Companies also identified the spin-off of firms from universities as an important economic issue for the Commonwealth, and made a series of recommendations to facilitate this process. See "Renewing Venture Capital: Improving the Environment for Financing Emerging Companies in Massachusetts," July 27, 1995.

post-doctoral staff, and faculty, the results of such research are evaluated in prototypes of real applications by research staff. Development staff then produce software for distribution to members. A not-for-profit corporation then serves to assist in the transfer of the technology developed at CIIR and participates in joint ventures. Recently a new company based in Amherst, called Sovereign Hill was formed around the software package Inquery (developed at CIIR) which has been licensed to over 70 companies.

Industrial Consulting: Besides contracting and grants to universities, an important avenue by which university expertise is transferred to firms is through industrial consulting. While publicly available data is extremely difficult to obtain in this area, studies by Mansfield suggest that for high-technology industries such as chemicals, drugs, electrical equipment, and information processing, firms spend a considerable amount on academic consulting.[17] He estimates that such industry funding, as a percent of industrial expenditures performed at colleges, averages about 20%, implying that industry-supported academic research exceeds the figures generally provided by public reporting agencies.[18] Further, although firms do not confine their consulting relationships to local universities, geographic proximity is one factor that affects where such relationships are formed.

Based on qualitative evidence collected from interviews with industrial executives, Mansfield offers further support that consulting activities of university personnel are extremely valuable in this regard. Approximately two-thirds of academic consulting budgets are oriented towards work aimed at solving particular problems facing the firms, while the remaining third is for other purposes such as briefing a firm's personnel in a particular field of science. Furthermore, he finds that most academic researchers cited by firms as having contributed significantly to their new products had continuing relationships with at least some of the firms

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[17] Edwin Mansfield, "Industry-University R&D Linkages and Technological Innovation." Paper presented at the annual meetings of the American Economic Association , January 1996. See also Edwin Mansfield, "The Contributions of New Technology to the Economy." Forthcoming, the Brookings Institution and Edwin Mansfield, "Academic Research Underlying Industrial Innovations: Sources, Characteristics, and Financing," *The Review of Economics and Statistics,* 1995.

[18] According to Figure 2-2, this would be approximately $60 million (1993).

supporting their academic research, while their students have taken jobs with at least some of these companies.

Graduates: Given the high quality of its higher education institutions, it is not surprising that while Massachusetts ranked 13th in the nation in the overall size of its labor force, it ranked 4th in the number of science and engineering graduate students.[19] The high quality of our academic institutions has been one of the factors that attracts students to Massachusetts. While the individuals who study and train within these institutions prepare themselves to enter the labor force well-schooled in a variety of disciplines, they are also a rich source of new, young entrepreneurs, whose undertakings further contribute to the economic growth and development of the state. For example, a study by the Bank of Boston found that between 1980 and 1989, MIT alumni were responsible for the creation of 20 new biotechnology firms in Massachusetts.[20] Of course, actual enterprises exceed even these numbers, as a simple foray into the local business news reveals such examples as Immunetics Inc., which was started by a Harvard post-doctoral student; the client-server technology company Sapient, a Cambridge-based company co-founded by a Harvard graduate that employs about 200 workers and has an annual revenue of $250 million; and; T-breeders, started by a recent graduate of Worcester Polytechnic Institute, based on research while a student.

Technology parks and incubators: Technology parks and incubators have as a mission the localization of research and development by facilitating the transition from basic research to commercial application. Such institutions have, for instance, played an active role in transforming the Commonwealth's comparative strength in health-related research into the creation of a strong biotechnology sector. For example, Boston University's Medical Center has been instrumental in the creation of Biosquare, a biotechnology park, as well as developing the Community Technology Fund, a venture capital fund; Western Massachusetts business leaders and UMASS have recently created a unique public-private enterprise called Mass Ventures which will provide business start-up services to UMASS faculty and other high technology entrepreneurs in the Pioneer Valley and will be able to house them

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[19] *1993 Science and Engineering Profile*, The National Science Foundation.

[20] *MIT: Growing Businesses for the Future*, The Bank of Boston, 1989.

in the Mass Ventures Center now being constructed in Hadley, adjacent to the Amherst campus; and University Park at MIT leases space to high technology companies in general with a large concentration of biotechnology companies.

A particularly successful example is Massachusetts Biotechnology Research Institute (MBRI), in the Massachusetts Biotechnology Research Park in Worcester, adjacent to the UMASS Medical Center. A public-private venture started in 1987, MBRI has taken a multi-faceted approach for accelerating commercial development of biotechnology-based research. At the core of MBRI's approach is the Innovation Center, which provides laboratories, office space, and critical operating personnel to promising new biotechnology firms. Within the Center, the MBRI provides both scientific and business support. This includes the provision of, for example, specialized laboratory equipment as well as legal support, business services, and assistance in permitting. In return for its in-kind investments, the Institute receives equity in the new enterprises. Along with its venture capital arm, Commonwealth Bioventures, Inc. (CBI), the Institute has leveraged $6 million in public funding with over $55 million in new, private venture capital funds. By combining research facilities and access to capital, it has assisted in the creation of 20 new biotechnology companies and over 2,000 jobs. Several companies, such as the Phytera, have recently moved from the incubator to their own facilities.

Industry councils and networks: Providing a largely informal network of interaction, industry councils play an instrumental role in coordinating activities and disseminating information. That is, by providing an infrastructure for joint public-private events, such as technical and investor conferences, panel discussions, and other networking opportunities, the councils assist in facilitating the collaboration on ideas and exchange of information between and within the public and private sectors. For example, the Massachusetts Telecommunication Council and the University of Massachusetts will hold their second technical conference on telecommunications R&D in Massachusetts in March 1996 at UMASS Lowell, providing a forum for presenting new innovative research and emerging applications in telecommunications technology. In addition, the Council hosts an investor conference which brings together the state's top private and public telecommunication companies with potential sources of capital. Likewise, the Environmental Business Council of New England, an association of environmental and energy firms, undertakes a number of business development programs on behalf of its members, including seminars on financial, domestic, export, marketing, and relevant development issues.

In addition, such councils often seek to improve the general state of public knowledge about the role and needs of high technology within the state, as well as improve the educational opportunities in and about the various industries. The Massachusetts Biotechnology Council, a Cambridge-based organization comprised of over 160 companies and institutions, and the MBRI undertake a number of educational outreach programs which provide information and training to students and educators (at all levels), state officials, and the general population. The Massachusetts Software Council is a co-conductor of the Software Council Fellowship Program, which is designed to assist workers in making the transition from the hardware sector of the computer industry to the software sector. Also, the Massachusetts Chemical Technology Alliance, an association of chemical manufacturers, has involved its members companies in a joint R&D program with the National Environmental Technology for Waste Prevention Institute (NETI), working together to find ways to prevent harmful waste production in manufacturing processes.

IV QUANTITATIVE ESTIMATES OF THE CUMULATIVE IMPACT OF REDUCTIONS IN FEDERAL RESEARCH SUPPORT

As discussed in the previous section, reductions in federal research support affect the Massachusetts economy through direct demand effects, induced demand effects, and supply or innovation effects. In order to estimate the magnitude of these effects, we use a computer-based model of the Massachusetts economy developed by Regional Economic Models, Inc. ("REMI"). The REMI model provides a baseline or business as usual forecast of economic growth in Massachusetts. We have estimated the impact of federal spending reductions by utilizing the model taking into account changes in federal research support, *relative to the baseline forecast*. We then compare the levels of economic activity (as measured by Gross State Product or employment) projected by the model as adjusted by federal funding reductions, with the levels projected in the original baseline forecast.

IV.A Federal research support projections or scenarios

The first step in the modeling process is to forecast the contraction in overall federal research support levels. We have created two projections of what research and development funding levels will be -- the **declining spending scenario** and the **constant spending scenario**. Under the **declining spending scenario**, R&D funding levels for different agencies are derived from projections of discretionary spending that will bring the federal budget in balance by the year 2002.[21] (As discussed above, we have focused solely on the R&D component of the possible budget plans, ignoring the macroeconomic effects for the purposes of this study.) In this scenario, absolute research spending declines by varying amounts for different agencies. We consider this scenario as "worst-case" for the Commonwealth. As an alternative funding scenario with less severe cuts to R&D,

[21] At the time of writing, the actual budget numbers were still in flux. The declining spending scenario is derived from projections of civilian research support made by the American Association for the Advancement of Science, based on the concurrent budget resolution based by Congress in June 1995, combined with projections for defense-related research, development, testing, and evaluation from the Defense Department. For those agencies for which 1996 Appropriation bills have been passed, the actual 1996 appropriation number is used in place of the projections from the other sources. For more details, see the Technical Appendix.

we have constructed a **constant spending scenario** which maintains research support for each agency at its 1995 level, resulting in reductions from non-adjustment for inflation.

It is difficult to know how any projections in *overall* agency research support will translate into changes in the levels of support for Massachusetts institutions. Much of this funding, particularly in the area of civilian research, is distributed through "peer review" evaluation processes that, in principle, ensure that whatever funds are available will be granted to the most qualified researchers and the most promising research proposals. Massachusetts' disproportionate share of existing research funding testifies to the prestige of our researchers and the quality of their research. It is possible, therefore, that our overall high rankings in the peer review process might insulate our institutions somewhat from the effect of overall budget cuts, suggesting that the reduction in funding that we would suffer would be less than proportionate to the overall reductions.

On the other hand, there are a number of factors that suggest that we are likely to suffer our proportionate share of losses. First, program officers face pressure to maintain geographic diversity in their funding, so that an increase in our already-disproportionate share of the total might be viewed as problematic. Second, if budget reductions simply resulted in dropping proposals from the bottom of the peer review ranking, this would have a disproportionate impact on younger and less established researchers. Fearing this, program officers are likely to attempt to spread the pain around by cutting the budgets of all researchers rather than (or in addition to) funding fewer proposals. Third, an obvious way for agencies to try to cope with declining research budgets without scaling back the overall scope of research that they support is to reduce indirect cost recovery rates (discussed further below). To the extent that budget reductions are accommodated through reductions in indirect recovery rates, Massachusetts would presumably suffer in rough proportion to its overall research funding. Finally, even the best institutions do not get funding for all their proposals -- each institution has researchers near the funding margin, and hence many will lose funds if the cutoff is raised.

We cannot say how all these factors will sort out. For modeling purposes, therefore, we have simply assumed that the reduction in research funding for Massachusetts by each agency will be proportionate to the agency's overall funding reduction. To the extent that one believes we will be able to mitigate these reductions by increasing our overall share, our estimates would overstate the impact on the Commonwealth.[22]

In order to estimate the economic impact of reductions in federal research expenditures, it is not sufficient merely to identify what the spending levels will be. We also need to specify what spending levels *would have been* had the policy change being modeled not occurred. *In other words, the economic impact is driven by the differences between the funding levels in a given scenario and the funding levels in a baseline forecast.* This baseline forecast for federal research support must be consistent with the baseline economic forecast embodied in the REMI model. REMI does not contain explicit data or assumptions regarding research expenditures; we have developed implicit baseline projections for federal research support in Massachusetts from the REMI estimates of overall federal spending in Massachusetts, divided between military and civilian expenditures.

Figure 4-1 compares the resulting baseline projection for federal research spending in Massachusetts to the **declining spending scenario** described above. The baseline forecast (lines with diamonds in Figure 4-1) has federal support increasing between 1995 and 2002 at roughly the rate of inflation, resulting in inflation-adjusted research support that is about the same in 2002 as in 1995. This roughly constant overall level of support in real terms is a mixture of a projected increase (after adjustment for inflation) of 13% in civilian spending, combined with a projected *decrease* of 5% in military spending.

The **declining spending scenario** (lines with no diamonds in Figure 4-1) has actual reductions in expenditures, which translate into even larger reductions after adjustment for inflation. Under this scenario, overall federal support of Massachusetts research would be 34% lower, after adjustment for inflation, than it was in 1995. The other way to view the magnitude of this reduction is relative to the baseline forecast. Because the baseline forecast is close to constant in real terms, the comparison is similar: the **declining spending scenario** represents

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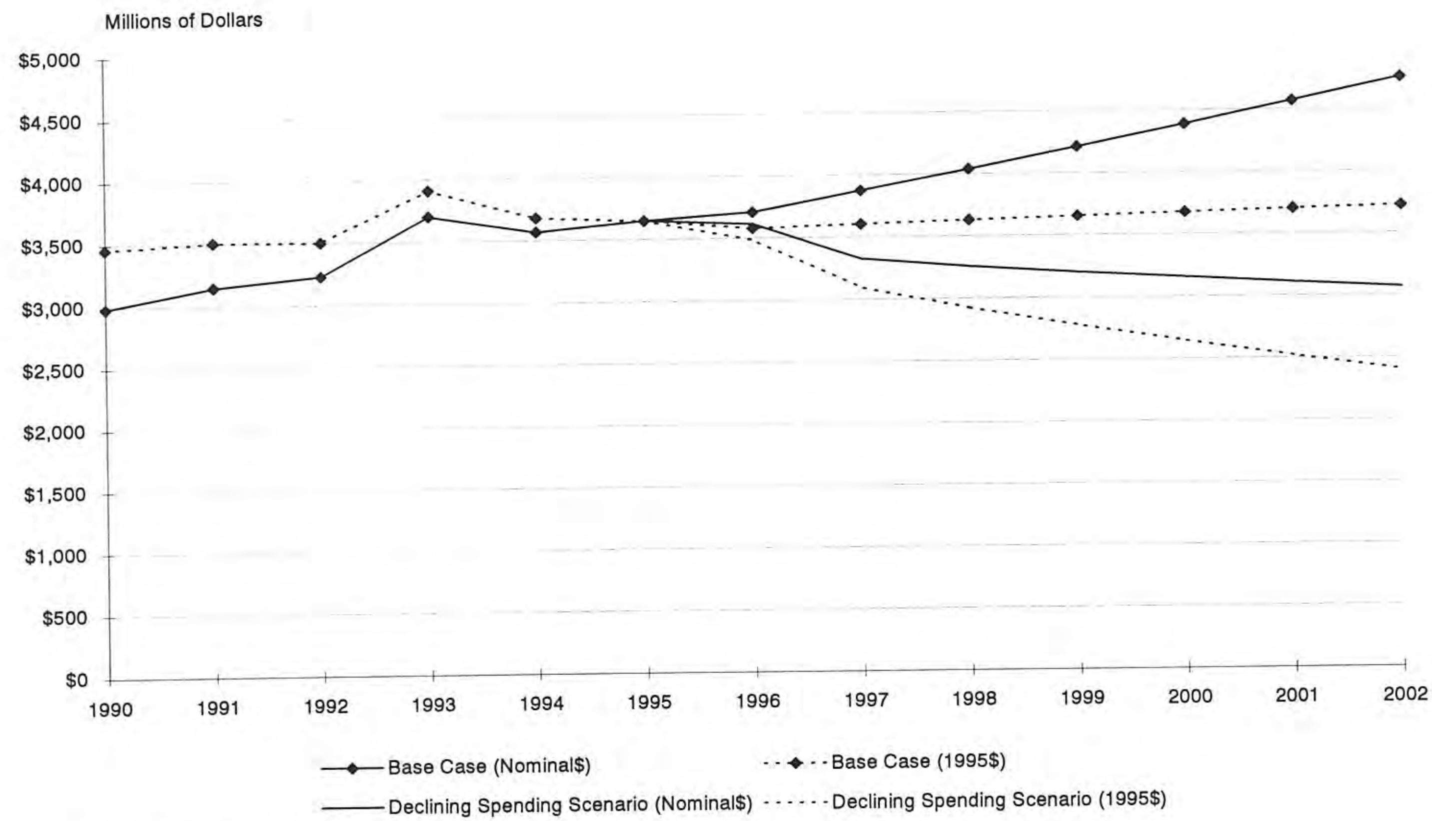
[22] The Technical Appendix presents more detail on how the individual agency funding forecasts are translated into funding changes by sector within Massachusetts.

Figure 4-1

Federal R&D Spending in Massachusetts:
Baseline Foresast Versus Declining Spending Scenario



Source: ERG calculations

funding in 2002 at a level 35% less than is projected to occur if there were no change in federal policy.

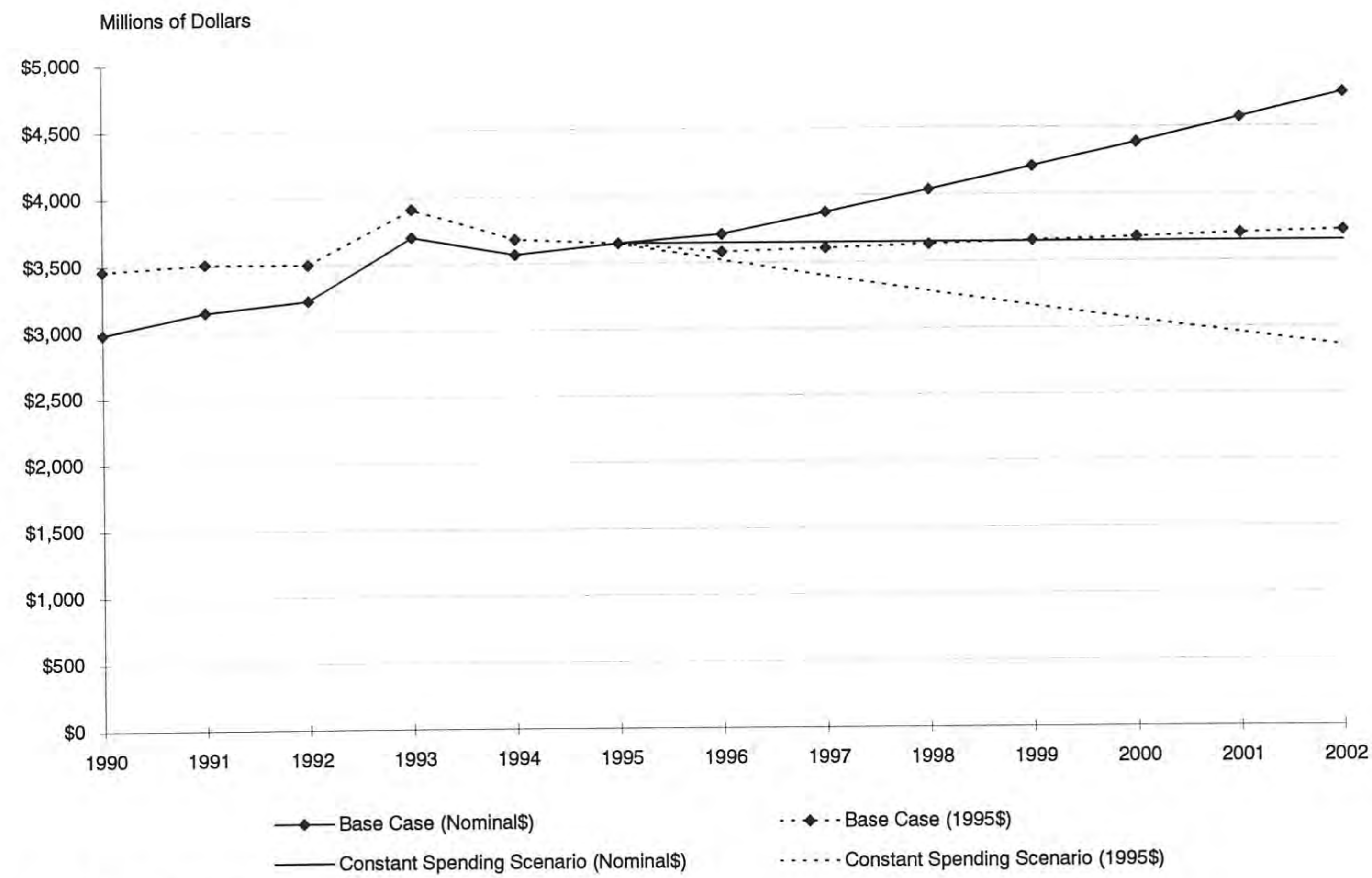
Figure 4-2 presents the same comparison for the **constant spending scenario**. Here, real spending declines over time due to the cumulative effects of inflation. Using the inflation rates forecasted by REMI, constant expenditure at 1995 levels corresponds by the year 2002 to a reduction of 22% after adjusting for inflation. As before, the comparison to the baseline is similar to the reduction in real terms, with the **constant spending scenario** at a level of funding that is 23% less than occurs in the baseline forecast.

Figure 4-2A graphically shows the levels of R&D spending under the three scenarios considered in this analysis. Under the baseline forecast R&D spending rises approximately with the rate of inflation from 1995 -2002, thus remaining constant in inflation-adjusted dollars. Over the same time period, the declining spending scenario would result in a reduction in federal R&D expenditures of 16% in nominal dollars and 34% in inflation-adjusted dollars.

Figures 4-3 and 4-4 illustrate the reductions, relative to the baseline scenario, across the major research sectors, for the **declining spending** and **constant spending scenarios**, respectively. The sectoral composition of the cuts is driven by the differences across sectors in the agencies on which they depend, combined with the fact that the baseline already incorporates significant declines in defense R&D, which is concentrated in industry. In the **declining spending scenario**, 47% of the reductions in the year 2002 relative to the baseline occur in industry, with 26% in universities and 15% in hospitals. Comparing the **declining spending** and **constant spending scenarios**, we observe that larger reductions in the **declining spending scenario** are concentrated in industry and "other" non-profits. In particular, the Department of Health and Human Services, the predominant funding source for hospitals, has close to constant spending even in the **declining spending scenario**, so the difference between these two scenarios is concentrated in the other sectors.

The differences across the non-profit sectors are illustrated in a different way in Figure 4-5. It shows the change, relative to 1995, in federal support for research in the three non-profit sectors. For the university and hospital sectors, the

Figure 4-2
Federal R&D Spending in Massachusetts:
Baseline Forecast Versus Constatnt Spending Scenario

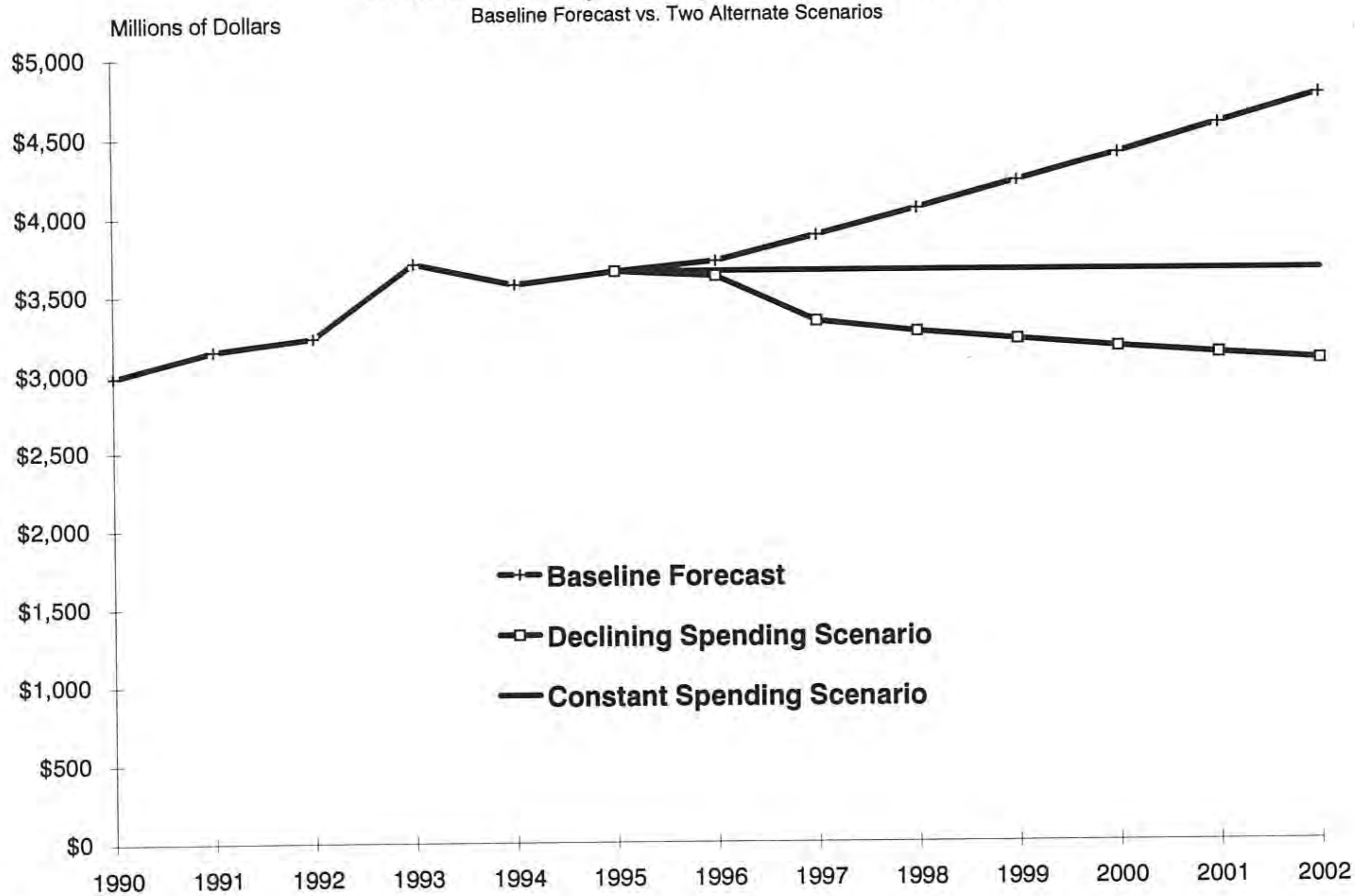


Source: ERG calculations

Figure 4-2A

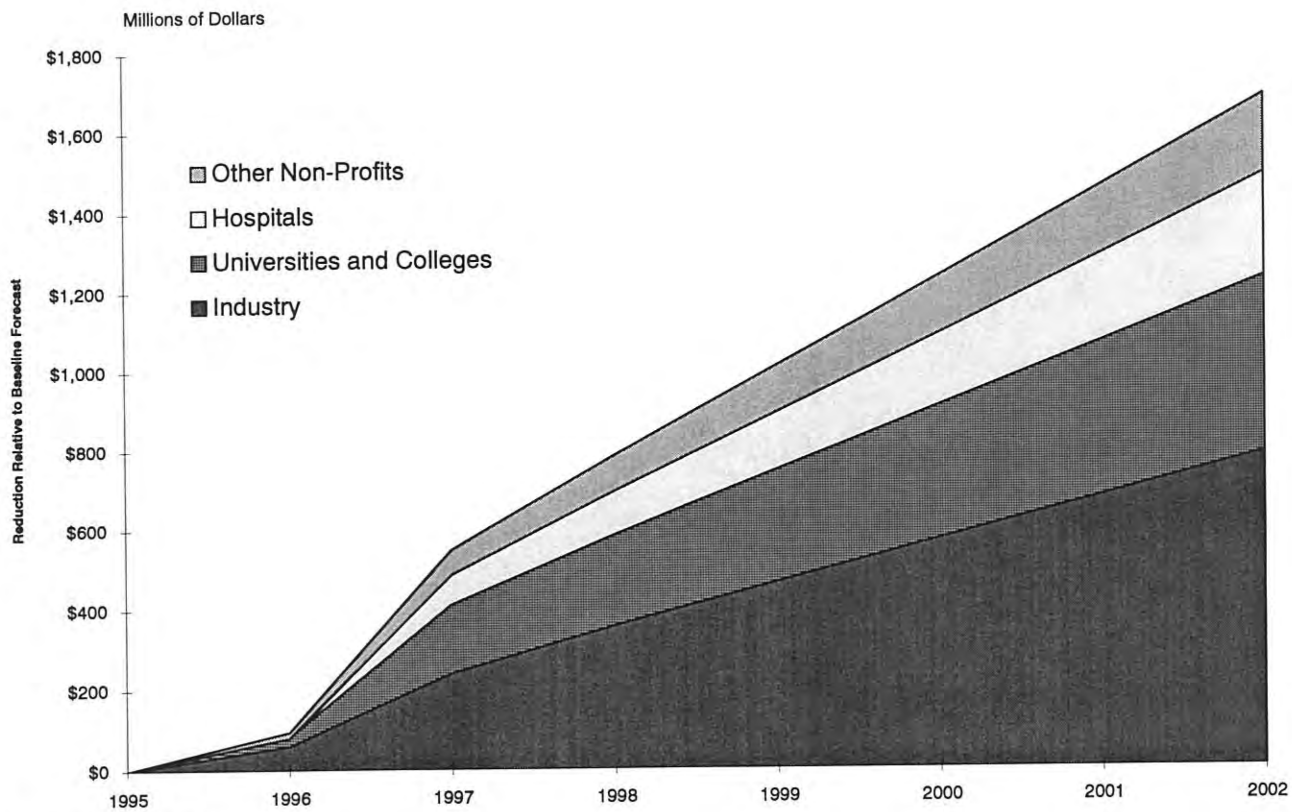
Federal R&D Spending in Massachusetts:

Baseline Forecast vs. Two Alternate Scenarios



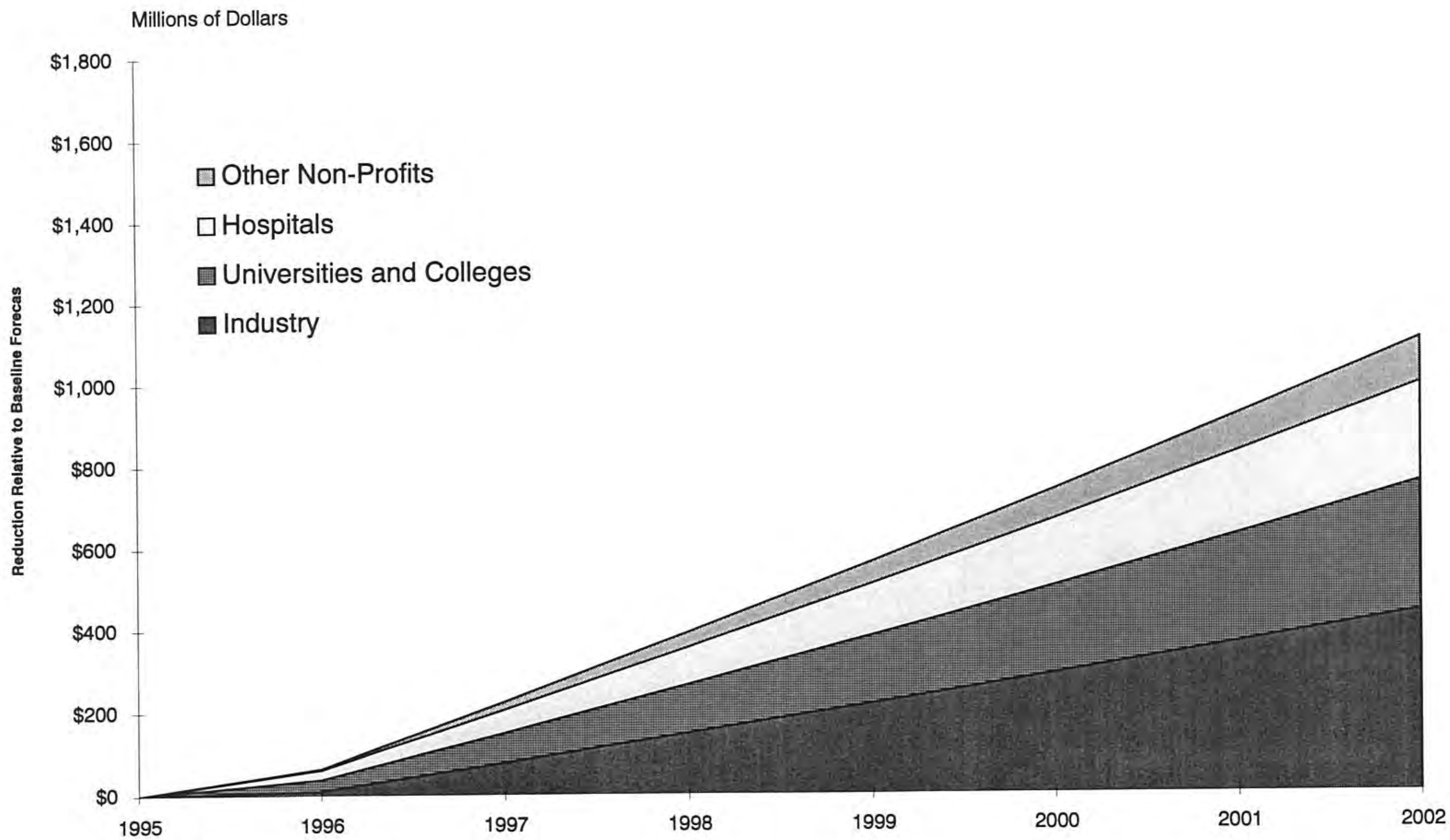
Source: ERG calculations The Massachusetts Technology Collaborative and The Economics Research Group, Inc.

Figure 4-3
Projected Cuts in Federally Funded R&D by Sector
Declining Spending Scenario



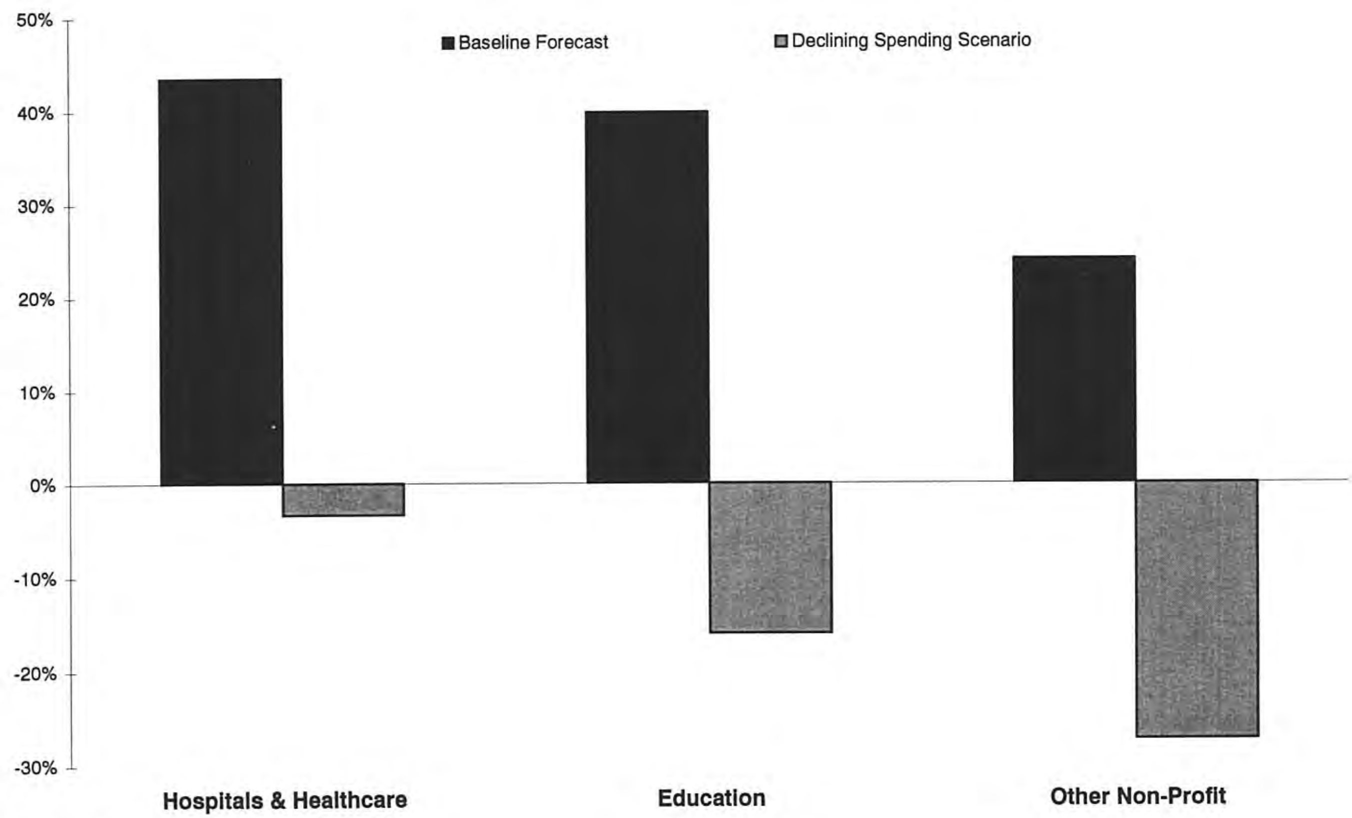
Source: ERG calculations

Figure 4-4
Projected Cuts in Federally Funded R&D by Sector
Constant Spending Scenario



Source: ERG calculations

Figure 4-5
Change in Federal Research Funding from 1995 to 2002:
Universities, Hospitals, and Other Non-Profits
Declining Spending Scenario



Source: ERG calculations

difference between the **declining spending scenario** and the baseline forecast is the result of increases in the baseline combined with modest nominal decreases in the **declining spending scenario**. In contrast, the other non-profit sector, reflecting its greater dependence on military R&D, shows a smaller increase in the baseline and a larger decrease in the **declining spending scenario**. In other words, the baseline already contains a less optimistic forecast for this sector, so that even though its support declines more in absolute terms, its reduction relative to the baseline is not very different than the other sectors.

IV.B Institutional responses to declining support

The previous section describes two scenarios for changes in federal research support in Massachusetts, relative to what might otherwise have occurred. The changes in *overall* research spending will be driven by these changes in federal support, but will also depend to some extent on how the affected institutions respond to declining federal support. Can increases in support from other funding sources, *over and above increases that would otherwise have occurred over time*, offset the projected declines in real federal support? In this section we consider some issues surrounding this question. Our ultimate conclusion is that, at least in the long run, the most likely outcome is that other funding sources will not significantly offset the cut in federal research support, implying that the change in overall research spending will be approximately equal to the change in federal research spending.

Overall scale. The simplest reason why other funding sources are unlikely to offset federal reductions to any significant degree is the sheer magnitude of the numbers. Federal funds constitutes 70 to 80% of sponsored research support at Massachusetts universities and hospitals. Even relatively large proportionate increases in the other funding sources would not make a significant difference relative to the magnitude of the dollars being lost.

The indirect cost recovery issue. Federal research grants provide money to research institutions to cover both the direct costs of research (salaries, stipends, equipment, supplies) and the indirect costs, including institutional overhead expenditures and fixed costs, such as rent or amortized building construction costs.

Payment for indirect costs is received in the form of a percentage, called the indirect cost ratio, that is added onto the direct costs of a research proposal. In recent years, funding agencies have exerted increasing pressure on institutions to reduce indirect cost ratios. As mentioned above, one mechanism by which agencies might effectuate across-the-board budget reductions is to seek to reduce indirect cost recovery rates even further. To the extent that this occurs, research institutions would, in effect, be *forced* to make up the decline in federal support through an increase in the contribution that they make to research from their own funds. Should there be a federally-imposed indirect cost cap, Massachusetts institutions will be disproportionately harmed, since their indirect costs are above average. In addition, much industry sponsored research pays indirect costs at the same rate as the federal government. To paraphrase the words of one research administrator who participated in the study: the federal government can cut the indirect cost payments, but the hospital still has to make the payments on the revenue bonds that were issued to pay for the construction of the building in which the research occurs.

Thus, in the short run, the possibility that research funding reductions will occur disproportionately in indirect costs might mean that research *activity* would be partially insulated from the reductions, as *direct* research funding falls less than overall funding and research institutions are left to cover indirect costs by some other means. But this outcome cannot persist in the long run. Research institutions cannot print money. If a greater share of the indirect costs of research is shifted to these institutions, they can cover the resulting deficit in the long run only by increasing external funding from some other source, by subsidizing the research function out of revenues generated from their health care or education functions, or by reducing fixed costs by postponing construction and rehabilitation projects or reducing staff.[23]

Prospects for increasing the share of the federal pie. As discussed above, it is possible that the peer review process might permit Massachusetts' world-class institutions to increase their share of the shrinking federal pie. In addition,

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[23] In the short run, some institutions could cover the funding deficit by tapping into their endowments, but this is obviously not sustainable in the long run.

particular institutions might be able to improve the quality of their research proposals, their political and other activities in support of their researchers, or both. There is no avoiding the fact that this is a zero-sum game overall. Institutions in every other state will be redoubling their efforts to win federal grants. It seems imprudent to assume that Massachusetts institutions will succeed in increasing their already-disproportionate share.

Prospects for increased industry funding. Some Massachusetts institutions could probably increase their level of industry research support. There are several reasons, however, why increased industry support is unlikely to replace lost federal funding to any significant degree. First, most experts do not foresee large increases in industry research spending overall in the near future. Real industry spending on R&D in the last few years has been flat or declining in real terms. Thus, increased industry funding of university research would have to come at the expense of spending in firms' own laboratories. Second, industry does not, for the most part, support academic research for philanthropic reasons. Industry supports academic research because it expects to benefit from the results. In particular, industry spending is intended, to a large degree, to facilitate the application of new basic research results to applied problems, and to effectuate the transfer of new research results into the commercial sector. Thus, industry research and government-funded research are, to a significant degree, *complements* rather than substitutes. If the flow of government-funded basic research slows, there will be, in a sense, *less* reason for industry to fund academic research, rather than more.

Prospects for increased state funding. As noted above, state funding of university research is about 1.5% of the total in Massachusetts. Even large percentage increases in this funding would have relatively little impact, and large increases are unlikely in the current fiscal environment.

Prospects for increased funding from other revenues. At universities, the only other major revenue source is tuition. As the recent debates surrounding tuition for state colleges demonstrates, there is a general view that tuition is already too high. At private institutions, commitment to need-blind admission and financial-aid policy limits the extent to which tuition increases yield greater revenue. Hence it seems unlikely that research activity could be sustained in the face of declining funding by raising tuition.

The situation at hospitals is even more bleak. In addition to uncertainties from structural change and revenue pressure from managed care, hospitals are likely to face significant declines in the revenues they receive for treating Medicare and Medicaid patients. Massachusetts hospitals could lose as much as $1 billion in Indirect Medical Education payments over the period 1996-2002.[24] In comparison, the cuts in research funding to the hospital sector, relative to the baseline, in our **declining spending scenario** amount to $984 million over this same period. Thus, rather than being in a position to offset the cuts in research support with revenues from other sources, the hospitals face an aggregate funding shortfall that is twice as large as what we have modeled.

Indeed, a case could be made that the loss of revenues from patient treatment will cause research activity in the hospital sector to decline even more than would be expected based on the cuts in federal research support. In the short run, this is unlikely to be true. Regardless of whether or not the hospitals are losing money, and regardless of whether or not federally sponsored research fully covers indirect costs, it will be in the interests of hospitals to pursue federal research grants, and, presumably perform the research to the extent that they get the grants. However, the ability of hospitals to provide support for younger researcher or bridge support between grants is declining as federal research support reductions are coupled with other cost pressures faced by hospitals. In the longer run, however, the research picture at hospitals is less clear. If major institutions go bankrupt, or, more likely, engage in consolidations that result in reduced faculty and other research staff, then there will be fewer people engaged in research and research-related activities and hence fewer grant proposals and less sponsored research. On the other hand, medical institutions all over the country will be facing similar pressures; if everyone submits fewer proposals, then any given proposal will be more likely to be funded. In other words, the issue comes back to what happens to the Massachusetts share of the federal research pie. On balance, we see no strong reason to believe that it will either grow or shrink, implying that the proportional reduction in the overall budget is the best predictor of the impact on research in the Commonwealth.

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[24] *The Economic Impact of Medicare and Medicaid Cuts on Massachusetts*, The Howell Group, August 1995.

Prospects for increased philanthropic funding. The only other source of research funding for hospitals and universities (either through direct grants or other gifts) is foundations and wealthy individuals. Again, it seems unlikely that this source could make up any significant portion of the reduction, particularly given the larger financial needs that will be created by other reductions in hospital revenues.

Summary of likely institutional responses. In summary, our view is that the most plausible prediction for the impact of federal budget cuts on research activity in the Commonwealth is that such activity will contract by an amount roughly equal to the decline in federal research support. In the long run, this means that faculty and other researchers will have less direct research support, that buildings and equipment needed for research will not be modernized as rapidly, and that research staff will contract. It is important to emphasize that this does not mean that individual institutions will all contract proportionately. Some will do better than others. Moreover, the conclusion that, in the long run, research activity is likely to decline by an amount roughly equal to our current share of the overall budget decline does not mean that specific institutions will not suffer severe financial distress along the way. In the short run, declining coverage of indirect costs will force institutions to reduce non-research activities or draw down endowments. In the long run, reductions in Medicare and Medicaid reimbursement could wreak financial havoc, even if institutions continue to perform federally sponsored research.

IV.C Overview of the REMI model

The REMI (Regional Economic Models, Inc.) model is a widely used, commercially available tool for understanding the economic impacts of events such as changes in U.S. government policy. Its core is an input-output structure for distributing final demand among various sectors of the Massachusetts economy. That is, the core of the model estimates transactions among industries, and uses these data for analyzing the interdependence between sectors and the impact which changes in one sector have on another. The REMI model utilizes standard statistical techniques for interconnecting the various sectors of the model. (This particular project utilized a 53-sector version of the model of the state's economy, which was specifically calibrated to examine the reduction in the flow of federal expenditures.) The model also takes into account the extent to which industries sell to other firms or households within the state and the extent to which they export to the rest of the U.S. or the rest of the world.

Because it incorporates the linkages among industries, REMI quantifies the overall effect of a spending reduction, including "multiplier" effects that occur as the reduced spending leads to lower income and hence further reduced spending by downstream firms and industries. For example, decreases in R&D spending reduce salaries and purchases of other goods and services. The decrease in salaries means that dollars will not be spent again on goods and services that those employees demand. In addition, the firms that provide goods and services to the R&D-performing sector will experience a decrease in demand. REMI uses historical information regarding purchases of inputs by each sector from other firms within the state in order to capture the overall impacts on the state's economy.

IV.D Incorporating direct demand, inducement and supply/innovation effects into the REMI model

In order to quantify the effects of the **declining spending** and **constant spending scenarios**, the REMI model is run first to produce the baseline forecast of economic activity in the Commonwealth. The model is then estimated for the other two scenarios, and the resulting levels of economic activity are compared to the baseline forecast. The resulting differences are the estimated impacts of the scenario. The Technical Appendix describes in some detail the steps necessary to model the direct demand, inducement and supply innovation effects of each scenario in the REMI model. The steps can be summarized as follows:

1. The direct demand effects of reductions in federal spending to the university, hospital and various industrial sectors[25] is captured by entering the difference between the scenario being modeled and the baseline forecast as a reduction in the output of the affected sector.

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[25] The reductions in federal support for the "other non-profit" sector are incorporated in the REMI model along with the projected reductions for firms in the Research and Engineering Services sector.

2. The induced R&D effect is modeled by calculating a further reduction in R&D in major R&D-intensive sectors,[26] using a statistical estimate of the inducement effect[27] distributed across industries using the patent citation analysis described in section III.

3. The supply/innovation effect is modeled by assuming that the direct and induced reductions in research will reduce the growth rate of the affected industries after a lag of 6 years.[28] The magnitude of the growth rate reduction is estimated using published statistical estimates of the average rate of return to research of different types.[29]

In order to get some perspective on the magnitude of these effects, Figure 4-6 shows the overall change (in nominal dollars) between 1995 and 2002 in estimated research spending by industry. The difference in each case shows the combined effect of direct reductions in federal funding of research in the industry, plus the reduction in firms' own spending calculated to be induced by the reduction in academic research. Not surprisingly, the largest reductions are in those industries -- Electric and Electronic Equipment, Transportation and Aerospace and Engineering and Research Services -- in which a large fraction of current research is federally funded. Indeed, for Transportation and Aerospace, in which over 65% of research is currently federally funded, the **declining spending scenario** implies an absolute reduction in the level of research spending by the year 2002. The other industries show significant reductions in the amount of growth, with Electrical

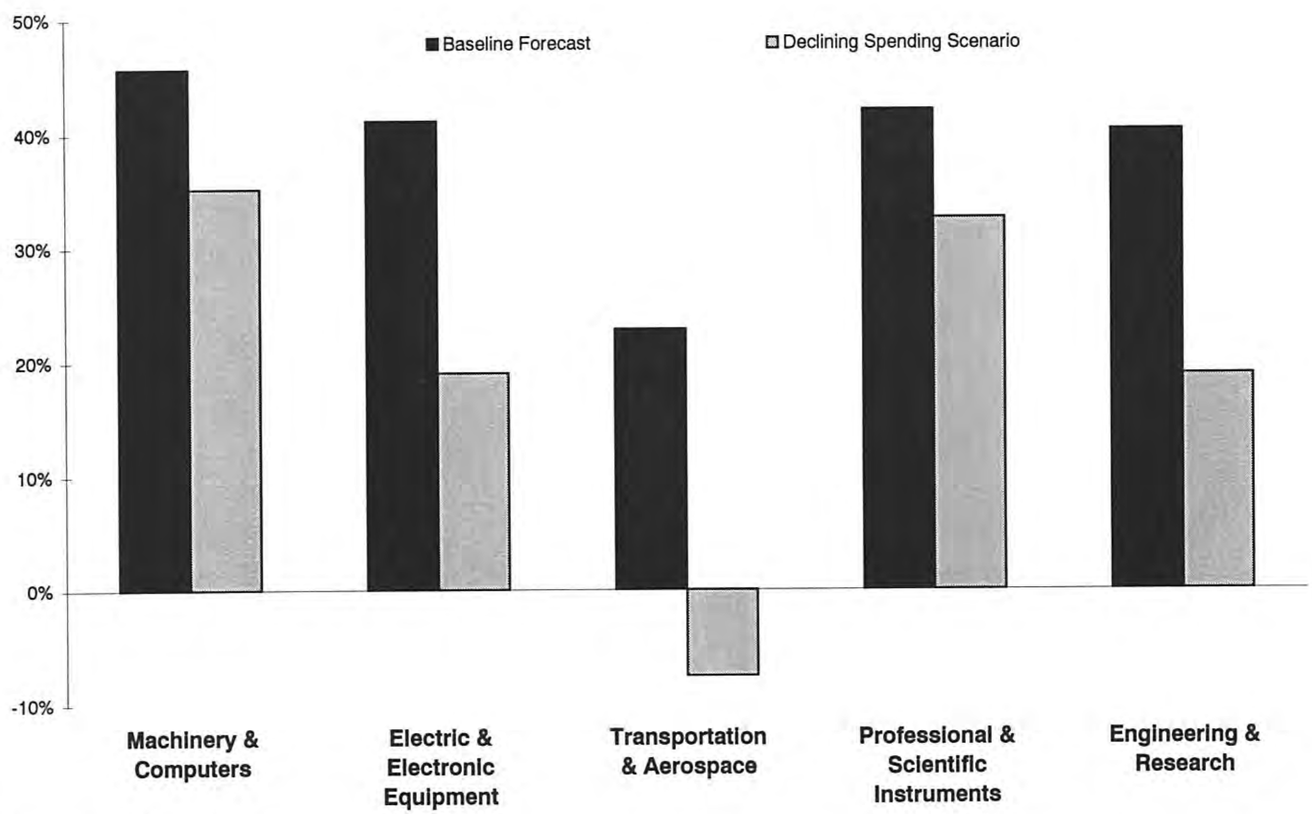
[26] Chemicals and Drugs, Machinery and Computers, Electrical Equipment, Transportation and Aerospace, Instruments, and Engineering and Research Services.

[27] As estimated by Jaffe (1989).

[28] Mansfield (1996).

[29] The gross rate of return to privately financed R&D is taken to be 40% per year. The industry-level rate of return to federally funded industry research is discounted to 35% of the private rate of return (Zvi Griliches, "Productivity, R&D, and Basic Research at the Firm Level," *American Economic Review,* March 1986). The direct spillover effect of university research on industry innovation is based on the estimate in Jaffe, 1989, converted to an equivalent reduction in industry research and then given the same rate of return as industry research. See Technical Appendix for more detail.

Figure 4-6
Change in Total Research Funding from 1995 to 2002:
Industry
Declining Spending Scenario



Source: ERG calculations

Equipment and Engineering and Research Services growing at slightly less than the inflation rate.

The other two major sectors, Machinery and Computers and Professional and Scientific Instruments, do not have significant federal support but are significantly affected by an induced reduction in spending because of cuts to research in the non-profit sector that generate spillovers in these industries. Both of these industries would still, however, see overall research expenditure within the Commonwealth increase by more than 30% by 2002, more than enough to offset expected inflation.

The supply/innovation effect results in modest reductions in the growth rate of output in the affected industrial sectors. The assumed 6-year lag between reduced research and reduced industry growth, combined with the fact that reductions in growth are cumulative over time, cause the supply/innovation impact to reach a maximum level well after the turn of the century. In the year 2010, the level of output in the affected industries would be 2 to 7 percent lower in the **declining spending scenario** than in the baseline forecast, with the largest effect being in transportation and aerospace and the smallest in instruments.[30] For most of these industries, these reductions relative to the baseline forecast would still allow positive overall growth in inflation-adjusted output. In other words, the **declining spending scenario** reduces but does not eliminate the real growth in these industries over the next 15 years. For transportation and aerospace, zero growth in inflation-adjusted output, combined with the large reductions in federal support, lead to an output level in 2010 in the **declining spending scenario** that is actually 21% lower than in 1995.[31]

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[30] Because it produces research rather than "products" in the normal sense, we have not included a supply/innovation effect for the Research and Engineering Services sector. For more detail on the supply/inducement effects, see the Technical Appendix.

[31] Growth in real output in this sector in the baseline forecast is -1% by 2010 as compared with 1995.

IV.E Overall impacts

Figures 4-7 and 4-8 summarize the estimated impacts of the two policy scenarios. Figure 4-7 presents the reduction in Massachusetts employment for each scenario, and Figure 4-8 illustrates the reductions in Gross State Product. In the **declining spending scenario**, the job loss relative to baseline levels is about 17,000 in 1997, rising to 37,000 in the year 2002. These short-term impacts are due primarily to the direct demand effect from the loss of federal dollars (including the "multiplier" effects captured by REMI). There is also a modest contribution from the induced industry R&D effect. In the longer run, the demand effects fade out,[32] but there is a significant effect due to reduced industry growth under the supply/innovation effect. By the year 2010, overall employment in the Commonwealth is about 50,000 less under the **declining spending scenario** than in the baseline forecast.

The effects under the **constant spending scenario** are similar, but smaller. Combined job losses from the three effects would total about 33,000 in 2010 under this scenario.

The losses in Gross State Product are also significant. As shown in Figure 4-8, losses relative to the baseline are about $900 million in 1997, rising to $2.1 billion in 2002 and $4.8 billion in 2010. The fraction of losses due to the supply/innovation effect are larger for Gross State Product than for employment, reflecting the high labor intensity of the education and medical sectors where the direct demand effects originate. Again, the pattern for the **constant spending scenario** is similar. Under this less extreme scenario, the 2010 GSP impact would be about $3 billion.

Overall, these reductions amount to modest but significant impacts on the overall economy of the Commonwealth. In the year 2010, private employment would be about 1.4% lower, and GSP about 1.8% lower in the **declining spending scenario** as compared to the baseline forecast. Overall, employment growth is

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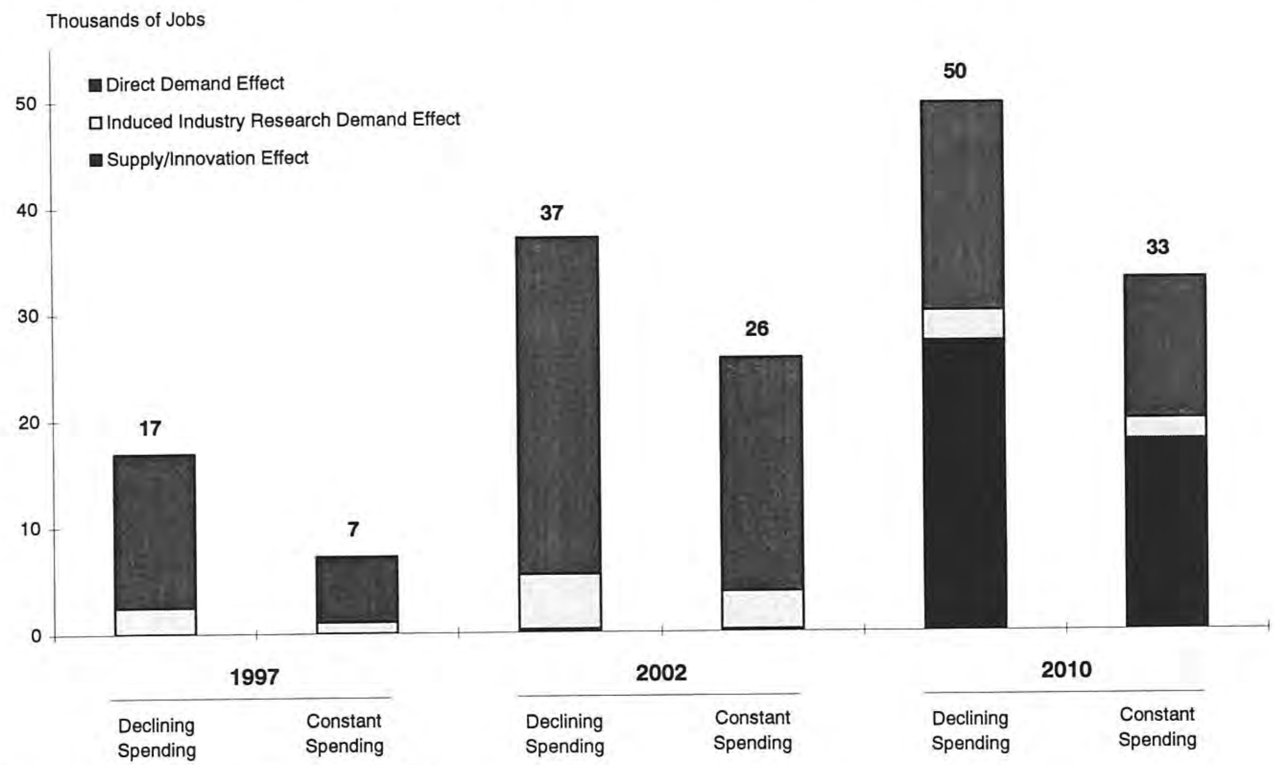
[32] In the long run (after 2002), we assume that federal research spending would grow in the declining spending scenario at the same rate as in the baseline forecast. That is, the difference between the declining spending scenario and the baseline would remain constant in nominal dollars after 2002.

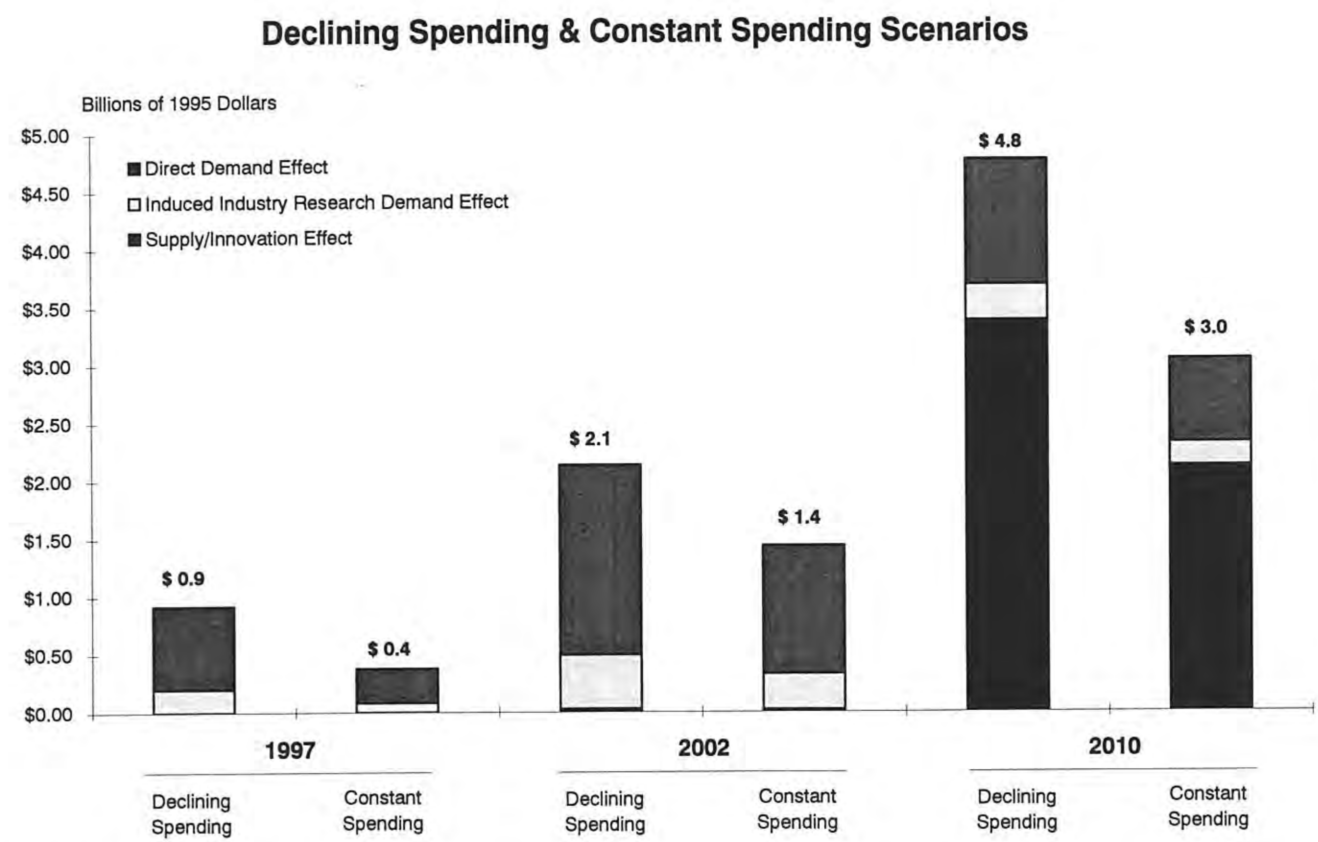
Figure 4-7
Impacts of Federal Research Cuts on the Massachusetts Economy: Employment Reduction Relative to Baseline Forecast

Declining Spending & Constant Spending Scenarios



Source: ERG calculations using REMI model

Figure 4-8
Impacts of Federal Research Cuts on the Massachusetts Economy: Gross State Product Reduction Relative to Baseline Forecast



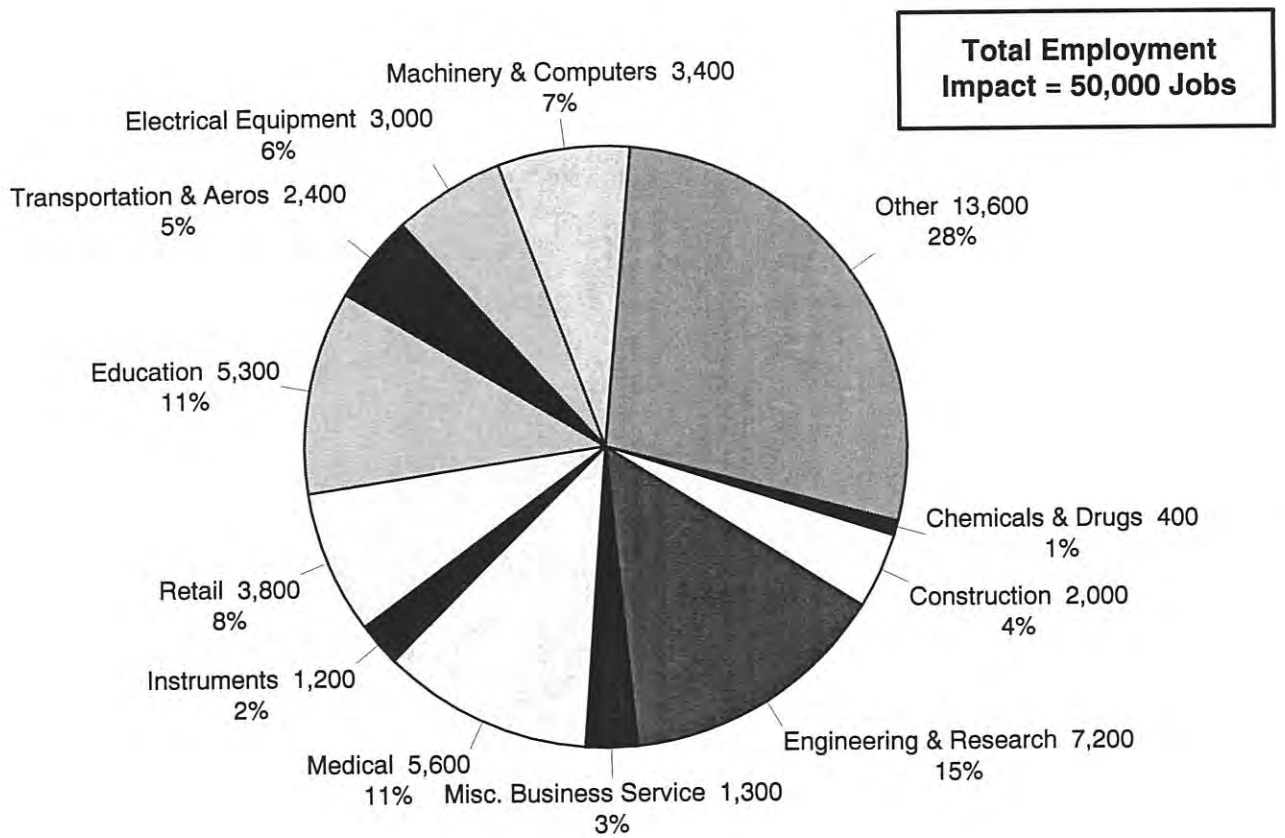
Source: ERG calculations using REMI model

reduced over the 1995 - 2010 period from 14% in the baseline to about 12.5% in the **declining spending scenario**, or a reduction in the growth rate of employment of greater than *total* employment growth in a typical year. In the **constant spending scenario**, 2010 employment would be reduced by 0.9% and GSP by 1.2%. One indication of the high quality of jobs is that these jobs pay far more than the average job in the state. In the past, these types of jobs have been an important component of the Commonwealth's continued growth. The magnitude of these losses reflect the vital role that research and innovation play in the state economy.

Figure 4-9 shows the distribution of long-run employment impacts across industrial sectors. The largest impacts are in the directly affected sectors of education, medical and engineering and research services. Because of the multiplier effects, however, there are also significant impacts in such sectors as retail trade and construction. Again, these numbers all represent reductions in employment relative to the baseline forecast. In the medical sector, for example, REMI forecasts an increase in employment of about 33% in the **declining spending scenario** between 1995 and 2010, despite the reduction relative to the baseline of about 5,600 jobs. Only in transportation and aerospace would employment in 2010 be lower than it was in 1995.

Figure 4-9

Distribution of Employment Impacts Across Industry Sectors Declining Spending Scenario: 2010



Source: ERG calculations using REMI model.

V ISSUES RELATING TO PUBLIC AND PRIVATE INITIATIVES TO STRENGTHEN THE RESEARCH INFRASTRUCTURE

The previous sections of this study have documented the critical role played by the research infrastructure in the economic growth of the Commonwealth, and estimated the magnitude of the adverse impacts that we confront as a result of proposals to reduce federal research and development expenditures. The development of a range of public and private responses to this situation will require an extensive dialogue among all of the affected stakeholders. As a foundation for that dialogue, this section discusses some of the policy issues raised by the foregoing analysis of the economic impact of research.

An unusual multi-party dialogue is called for. We have tried to demonstrate in this report that the Massachusetts economy is dependent on a complex web of interactions among the different components of the research infrastructure, and that the economic consequences of reductions in support for this infrastructure are significant. But the complexity and delicacy of this system suggests that our coarse, macroeconomic analysis could in fact understate the severity of the potential consequences. It is possible that funding reductions of the magnitude being contemplated will alter fundamentally the character of some of Massachusetts' premier research institutions, leading to a disruption in their contribution to the economy that goes far beyond the smooth, proportionate effects we have modeled for this report. The danger of such severe, discontinuous effects reinforces the need for ongoing monitoring of the situation as it unfolds, and the undertaking of a dialogue among the private sector, the non-profit sector and government to develop an effective, integrated response.

Differing objectives. This policy dialogue will have to take place against the backdrop of the somewhat different concerns and objectives of the various interested parties. The focus of this report is the economic development impact of research activities. This is a major concern of both public and private decisionmakers in the Commonwealth. But it is not, of course, the only or even the primary concern or objective of many research institutions. Universities are primarily concerned with teaching and research; hospitals are primarily concerned with patient care and research; firms are primarily concerned about their profitability; and even state government has to balance economic development objectives with a host of other policy concerns. All of these institutions are willing (to varying degrees) to make economic development for the Commonwealth a secondary or subsidiary objective, and/or to cooperate to some extent with other parties in common action for the good of the regional economy. But any efforts in this area must be pursued in such a way that the actions or roles contemplated for the diverse stakeholders are not inconsistent with their individual underlying missions.

Differing objectives converge somewhat in the long run. In the long run, everyone in Massachusetts shares an interest in the health and vitality of both the research institutions and their links to the economy and the population of the state. If the policy dialogue can be kept focused on these long-run objectives, then there is significant room for agreement and cooperation for that common public good.

Possible leverage points. At a broad conceptual level, there are three ways that the contribution of science and technology to economic growth within the Commonwealth can be enhanced:

(1) the scale of research activity in either the non-profit or industrial sectors can be increased;

(2) the rate or effectiveness of transfer of technology from the non-profit sector to the industrial sector can be enhanced; and

(3) the likelihood that spillovers from non-profit research are captured within the Commonwealth can be increased.

Participants in the policy dialogue are likely to differ as to which of these different levers they can influence. This is one of the reasons why it is important to involve all sectors in the discussion. Given the sheer size of the forecasted reductions in federal support, it seems unlikely that any combination of public and private actions within the Commonwealth could offset them completely. It may be possible, however, to significantly mitigate the economic impact of the cuts by increasing the efficiency of technology transfer and/or the extent to which technology transfer and spillovers are localized within Massachusetts.

Scale / localization tradeoff. As we move from the non-profit research sector, to research and development efforts in the for-profit sector, to commercial production of new products or implementation of new processes, the scale of possible impacts and the likelihood of localization within the Commonwealth generally move in opposite directions. That is, non-profit research institutions are almost entirely within-state institutions; any change in their activities will have all of its (direct) economic impacts within the Commonwealth. The spillovers from that research to research and development activities in the for-profit sector will not be confined to the Commonwealth, but, as discussed above, significant localization of such spillovers is likely because active communication between basic researchers and scientists and engineers involved in development is often necessary. If and when a technology moves to the production stage, such active communication may be less important, so that a product conceived in a Massachusetts university and nurtured in a Massachusetts corporate laboratory may be manufactured in North Carolina or Taiwan. Thus the probability of "capture" of benefits as a consequence of geographic localization falls as we proceed from university research, through industry research to commercialization.

On the other hand, the scale of *potential* economic impact will generally increase at the same time the likelihood of localization is decreasing. That is, if we trace the trajectory of a particular technology, the number of people employed will typically be very small at the university, somewhat more at the industry R&D phase, and larger still at the production stage. As a result, even though a significant fraction of the industry R&D, and much or most of the commercial production, induced by non-profit research may be outside the state, it is possible that the employment impact on the state may be larger at the industry R&D stage, and larger still at the production stage. This suggests that increasing the probability that new technologies stay within the Commonwealth all the way through to the production stage may be an important aspect of maximizing the economic return from research.

Start-ups or "spin-offs" are a crucial part of the process. The above discussion suggests that a climate conducive to the formation of new firms in general, and academic spin-offs in particular, is an important component of an approach to technology-based economic growth. This observation is not new,[33] but it is reinforced by several aspects of our analysis of the spillover process. New firms are more likely to be in Massachusetts than other academic licensees, and they are more likely to keep the higher-employment, larger-scale production phase of a product within the state. In addition, a climate conducive to formation of new firms will help to keep entrepreneurially minded graduates of local institutions living within the Commonwealth.

Match between public research strengths and industrial base. Spillovers from non-profit research are more likely to be localized to the extent that the particular industries most likely to develop the new technologies are located within the state. Thus the extent of match between the areas of scientific strength of the Commonwealth's universities and the areas of technological strength of the Commonwealth's industrial base will be an important factor in our ability to capture the spillovers. Specific efforts to support technology development and/or transfer are most likely to be successful in areas where the Commonwealth has strength in both the non-profit research and industrial sectors. Identifying such areas of potential match will facilitate the development of effective public/private initiatives.

Inducement may be as important as direct funding. As discussed in the previous section, both broad statistical studies and the detailed examination of licensees by MIT suggest that the amount of money that industry is induced to spend in developing university technology may be large relative to any amount of direct funding that local initiatives are likely to make available. Similarly, the induced impact on industry or hospital R&D of government procurement or health care funding may be large relative to actual government funding of research itself. This suggests that these inducement mechanisms are at least as important as funding mechanisms. In ongoing efforts to monitor the status of the research

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[33] "Renewing the Venture Capital: Improving the Environment for Financing Emerging Companies in Massachusetts," Governor's Council on Economic Growth and Technology Task Force on Financing Emerging Companies, July 1995.

infrastructure, attention should be paid to these inducement effects along with direct funding changes.

Different aspects of research infrastructure interact. As discussed in Section III, the research enterprise in the non-profit sector contributes to the economy through several different pathways. These different pathways or mechanisms interact in a variety of complicated and generally mutually reinforcing ways. For example, the production of skilled graduates provides, to some extent, the pool of talented and creative individuals from which are drawn the entrepreneurs who start new firms to exploit specific technologies developed at universities or hospitals and to which funding -- public and private -- is attracted. This suggests that reductions in research support for graduate students may have disproportionately adverse impacts, as the flow of both new technologies and new entrepreneurs is reduced. This kind of interaction has to be taken into account in considering policy responses; spending reductions in certain categories or certain institutions may have a wholly disproportionate impact, to the extent that multiple interacting spillover mechanisms are affected.

VI CONCLUSION

The size and quality of its research institutions are major strengths of the Massachusetts economy. Over the last decade, increases in external funding for research have fueled growth in these institutions and the Massachusetts economy more generally. Research plays a larger role in our economy than in that of any other major industrial state, and our research institutions are particularly dependent on federal funding. As a result, impending reductions in federal research support constitute a significant threat to the economic health of the Commonwealth. Because of the spillover effects of academic research on high-technology industries, the economic impact of cuts in research would be cumulative and long-lasting.

Given the predominant role of federal funding in academic research, and the generally tight fiscal environment in which we live, it is unlikely that any set of actions within the Commonwealth could wholly offset the pending reductions in federal research support. The non-profit research sector faces a prolonged period of difficult financial circumstances, and a significant amount of reorganization and retrenchment is likely. Given this uncertain future, it is important that key participants in public agencies, the academic sector, and high-technology industries work together to preserve the scientific and technological strength of the academic sector, foster mutual transfer of knowledge between firms and non-profit institutions, and ensure that the economic environment of the Commonwealth is conducive to nurturing the seeds of new products and new companies that can be planted by the research enterprise.

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APPENDIX A: INTERVIEWS

We wish to thank the following individuals and organizations for their willingness to provide detailed information on how reductions in federal research support will affect the operations of their institutions and membership. Their contributions added to the richness and accuracy of this report. We thank Mike Fogarty and Eric Oldsman for their helpful comments that greatly improved the quality of this report. All errors, of course, remain the responsibility of the authors.

Individuals

Ms. Joyce Brinton, Harvard University
Ms. Shelby Calvert-Morris, Brigham and Women's Hospital
Dean Aram Chobanian, Boston University School of Medicine
Mr. William Corbett, Dana-Farber Cancer Institute
Mr. Marc Daniel, Children's Hospital
Dr. David Glass, Massachusetts General Hospital
Maj. Audie Hittle, Air Force Electronics Systems Center, Hanscom AFB
Mr. Frank Holmes, Beth Israel Hospital
Mr. Kei Koizumi, American Association for the Advancement of Science
Dr. Ronald Lamont-Havers, Massachusetts General Hospital
Mr. Michael Lanner, Beth Israel Hospital
Dr. Eric Oldsman, Nexus Associates
Dr. Ronald Newbower, Massachusetts General Hospital
Ms. Lori Pressman, Massachusetts Institute of Technology
Dr. William Terry, Brigham and Women's Hospital

Organizations

Environmental Business Council of New England
Massachusetts Biotechnology Council
Massachusetts Biotechnology Research Institute
Massachusetts Computer Software Council
Massachusetts Telecommunications Council

APPENDIX B: GLOSSARY OF TERMS

Baseline (or "business as usual") Scenario: Current spending level of federally funded research and development within the Commonwealth projected out into the future based on the growth rates of civilian and defense spending within Massachusetts as estimated by REMI. (See also Technical Appendix.)

Constant Spending Scenario: Estimated future spending level of federally funded research and development within the Commonwealth assuming the 1995 level of research support for each government funding agency is held constant in nominal terms. (See also Technical Appendix.)

Declining Spending Scenario: Projected federal funding for research and development based the June 1995 Concurrent Budget Resolution (and subsequent appropriations bills.) This scenario assumes that research spending in Massachusetts contracts proportionately to US funding by agency. Estimates of funding by agency were provided by the American Association for the Advancement of Science and the Department of Defense. (See also Technical Appendix.)

Direct Demand Effect: Effects on wages and purchases of other goods by institutions (profit and non-profit) due to the reduction in federal funding for research and development, including the "multiplier" effect of reduced purchases in industries that are suppliers of the research intensive sector.

Federal Funds for R&D (Federal Research Grants): Receipts for R&D performed by the company under Federal R&D contracts or subcontracts and R&D portions of Federal procurement contracts and subcontracts.

Federally Funded Research and Development Centers (FFRDCs): R&D-performing organizations administered by industrial, educational, or other institutions on a non-profit basis, exclusively or substantially financed by the federal government.

Induced Demand Effect: Effects on wages and purchase of other goods by a decline in *industrial* research activity undertaken as a result of a reduction in research in the *non-profit* sector. This effect occurs because industrial research is stimulated by research in the non-profit sector, as industrial firms commercialize innovations developed at universities and other non-profit institutions. Thus, this measure captures the effect on demand over and above the reduction in direct federal support received by the for-profit sector.

Licensing: The payment by a for-profit entity to the non-profit institution for the right to commercialized technological advancements developed at the respective institution.

Non-profit research sector: Universities, hospitals and other not-for-profit research laboratories and institutes.

Research and development: Basic and applied research in the sciences and engineering and the design and development of prototypes and processes, excluding quality control, routine product testing, market research, sales promotion, and other non-technical activities or routine technical services, and research in the social sciences or psychology.

> **Basic Research:** Original investigations for the advancement scientific knowledge not having specific immediate commercial objectives, although such investigations may be in fields of present or potential interest to the reporting company.
>
> **Applied Research:** Investigations for the discovery of new scientific knowledge having specific commercial objectives with respect to products or processes. (Applied research differs from basic research chiefly in terms of the objectives of the reporting company.)
>
> **Development:** Technical activities not routine in nature concerned with translating research finding or other scientific knowledge into products or processes. (Not included are routine technical services to customers or other activities excluded above.)

R&D intensity: The research and development expenditures as a fraction of Gross State Product.

Spillover Effects: Economic benefits derived from R&D that are not confined to the institutions undertaking the research.

Supply/Innovation Effect: Measures the effect of the "loss" of new technologies and processes (and hence the flow of new goods and services) produced in the Commonwealth due to the reduction in research in both the private and public sectors.

Technology Transfer: The exchange among different entities of the knowledge of, the existence of, and/or the operation new products or processes. In this context, the flow is principally from the not-for-profit to the for-profit.

TECHNICAL APPENDIX

This appendix provides more detail on the quantification of the direct demand, induced demand, and supply/innovation effects that are input into a regional model of the Massachusetts economy to model the impacts of cuts in federally funded R&D.

Federal research support and funding projections

R&D funding levels and mapping to REMI industry sectors: In order to estimate R&D spending in Massachusetts, we used the most recently available data from National Science Foundation (NSF) surveys. The most up-to-date information at the state level is for 1993; all of the R&D projections are based on R&D expenditures for 1993 as reported in Figure 2-2 in the main report. The NSF categorizes R&D expenditures across broad categories (university, industry, non-profit). In order to conduct policy experiments in the REMI model, R&D expenditures had to be mapped to specific industrial sectors. In the non-profit research sector, university R&D was assigned to the education sector and other non-profit R&D was split between the medical sector (for hospitals and other medically related research institutes) and the "miscellaneous professional services" sector that includes engineering and research (for other research laboratories including Lincoln Laboratories). (See Figures TA-1 and TA-2 for research funding at specific institutions.) Industry R&D was allocated to specific industries based on the latest available (1991) breakdown of industrial R&D. (See Figure TA-3.) On the industrial side, we focused on six broad industrial categories that accounted for a large percentage of R&D in the state of Massachusetts: chemicals and drugs; machinery and computers; electrical and electronic equipment; transportation and aerospace; and non-manufacturing. Non-manufacturing R&D was assigned to the REMI category "miscellaneous professional services" that includes engineering and research firms. This definition of industries at the 2 digit Standard Industrial Classification (SIC)-level is by necessity somewhat coarser than other common definitions of "high tech" industries. It was driven by the level of disaggregation that was available both in NSF research funding data and in the REMI model.

Allocation of funding across institutions by agency: Another important component of creating the funding scenarios is the source of federal funding. Different fields of science and engineering receive support from different governmental agencies. For this purpose, we utilized historical NSF data on the recipients of funding from different federal agencies.[34] (See Figure TA-4.) Based on their importance in Massachusetts, we focus on three broad sources of funds in our calculations: Department of Defense, Department of Health and Human Services (which includes NIH), and an all other category, which we have proxied with spending projections from the Department of Energy, the National Science Foundation, and the National Aeronautics and Space Administration. Since our policy experiment starts in 1995 and the most recent historical information is from 1993, funding levels in 1993 by sector are assumed to grow in proportion to overall funding to each agency, after controlling for the mix of funding sources that are specific to Massachusetts.[35]

R&D funding under the declining spending and constant spending scenarios: For estimates of future funding levels likely as a result of efforts to balance the budget, we use two sources. For research support levels from the Department of Defense, we use DoD projections for total defense-related research, development, test and evaluation by year.[36] For projections of civilian research support, we use projections prepared by the American Association for the Advancement of Science (AAAS), based on a concurrent

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[34] Federal obligations data was used to proxy for historical spending patterns. See *1993 Science and Engineering Profile*, NSF, for Massachusetts. The breakdowns within the "non-profit" sector (i.e. between hospital and health care and other non-profits) is an ERG estimate.

[35] Data for non-defense R&D from 1993 and 1994 comes from the American Association for the Advancement of Science (AAAS), *AAAS Report 19: Research and Development Fiscal Year 1994* and *AAAS Report 20: Research and Development Fiscal Year 1995*. The most up-to-date estimates of FY 1995 as well as estimates of FY 1996 spending came from the AAAS FY1996 projections (*FY 96 R&D Appropriations Update,* Table A as of January 10, 1996). At that time, only the budgets for the NIH, Department of Agriculture and the DoD were final. 1993-1995 defense information comes from *Historical Tables: Budget of the United States Government, Fiscal Year 1996*, Table 5.1, Executive Office of the President, Office of Management and Budget.

[36] *Historical Tables: Budget of the United States Government, Fiscal Year 1996*, Table 5.1, Executive Office of the President, Office of Management and Budget.

budget resolution passed by Congress on June 26, 1995.[37] We used the most up-to-date figures available at the time of writing for estimates of 1996 appropriation numbers.[38] The 1996 appropriations were in fact not as severe as originally suggested in the Concurrent Resolution. In fact, 1996 funding to the NIH increased in 1996. With these assumptions, the DoD and AAAS numbers allow us to estimate the rate of change in research funding levels over the time period 1996-2002. Thus, research funding in each sector is related to historical funding level, historical funding sources, and projected funding by agency.

Applying the growth rates by agency in the AAAS/DoD forecasts to the 1995 Massachusetts numbers results in the forecast labeled "declining spending" scenario in Figure TA-5. In each case, we assume that Massachusetts' share of each agency's research support will remain constant over time; equivalently, we assume that spending by each agency in Massachusetts will decline at a rate equal to the agency's overall rate of decline of research support. We discuss the reasonableness of this proportionality assumption in Section IV.B.

In addition, we created an alternative projection with smaller spending cuts, the "constant spending" scenario. In the **constant spending scenario**, spending across each type of institution remains at 1995 levels for the period 1996-2002. Of course, since there will be inflation, this constant spending will purchase less research over time. The bottom panel of Figure TA-5 shows the funding projections in the **constant spending scenario**, with overall R&D expenditures at $3.6 billion from 1996-2002.

R&D funding under the REMI baseline: In order to estimate the impact of these spending levels, we also need to estimate what the spending levels would have been under the **baseline** or "business as usual" scenario. The REMI model does not contain explicit data or assumptions regarding

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[37] House Concurrent Resolution 67. The figures incorporate AAAS assumptions about the distribution of funds over time.

[38] The most up-to-date estimates of FY 1996 spending came from the AAAS FY1996 projections (*FY 96 R&D Appropriations Update,* Table A as of January 10, 1996). Although these numbers were not final, the NIH budget had been finalized by that date.

research expenditures. It does, however, contain estimates of overall federal spending in Massachusetts, divided between military and civilian expenditures. For the purpose of our estimates, we have assumed that federal research support within these two broad categories would have grown over time at the rate assumed by REMI for overall federal expenditures in the state. Figure TA-6 shows the growth of federal expenditure levels from the REMI model, relative to the expenditure level in 1995. REMI's **baseline** forecast incorporates increases of 21% and 44% for federal military and civilian expenditures, respectively, in Massachusetts between 1995 and 2002. Applying the growth that REMI assumes for overall federal expenditures to the actual civilian and military research support in Massachusetts in 1995 results in the forecast labeled "Base Case Projection" in the top panel of Figure TA-5.

Direct demand effects

The direct demand effects are simply the difference between the **baseline** scenario and the **declining spending** or **constant spending scenario**. These cuts are summarized by sector from 1996-2002 for each scenario in Figure TA-7. Modeling the direct effects of reductions in federal research support is straightforward with the REMI model. We simply input the reductions in R&D expenditure by sector as reductions in the overall value of output or economic activity in that sector over time. REMI then adjusts employment and the output of other industries in response to this reduction in spending.[39]

Spillover Effects: Induced demand and supply/innovation effects

To estimate supply/innovation effects, we proceed in three steps. First, we use information regarding the rate of citation by firms in different industries to university and other non-profit patents to estimate the pattern

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[39] There are no budget projections beyond the year 2002. Because we wish to model long-run effects, we must make some assumption about what happens to spending levels beyond 2002. For simplicity, we assume that spending after 2002 resumes the rate of increase implicit in the REMI baseline forecast. In other words, the reductions of 1996-2002 represent a permanent reduction in the level of support, but that after 2002 there are no *further* reductions relative to the baseline projection.

of spillover influences of non-profit research across industries. Second, we estimate the reduction in company-funded research that is likely to occur in each of these industries as a result of the decreased flow of new science and technology out of Massachusetts non-profit research institutions. This "induced" reduction in research effort has demand-side effects similar to those resulting from reductions in federal expenditures. Finally, we take the reductions in federal non-profit research, federal industry research *and* induced industry research and attribute to each of these categories corresponding reductions in the rate at which new commercial products and processes are introduced. This is the supply/innovation effect, which we model as a reduction, relative to the REMI baseline, in the growth rate of output in the affected industries.

Allocating spillover impacts across industries. There are estimates in the economic literature of the overall impact of university research on firms in the private sector. In order to use these estimates in conjunction with the REMI model, these impacts must be allocated to particular industries, and we need estimates of the fraction of the impacts of university research that are absorbed by particular industrial sectors. As an indicator of these effects on particular industries, we examined data on the citations made by firms in their patents to patents taken out by universities and other non-profit institutions. Our assumption is that these citations are a proxy for technological impact, and hence the fraction of citations coming from a given industry is indicative of the fraction of technological impact enjoyed by that industry. Because the industrial location of impact will obviously vary with the nature of the research, we looked separately at citations from different kinds of institutions and different university departments.

For each type of non-profit institution, we examined the patents granted from 1963-1993. We modeled the departmental breakdown of university patents with a sample of patents from MIT, mapping departments into broad fields of science and engineering that correspond to NSF funding data. Then, we linked each non-profit patent with the patents that subsequently cited the non-profit patent. For all of the citers of Massachusetts non-profit institution patents, we matched a standard industry categorization (a two digit SIC code available from Compustat and other public sources).[40] In our analysis, we include only citations from for-profit companies. Figure TA-8 shows the breakdown of citations to a particular discipline or non-profit institution by companies in different industries. These results provide a "weighting matrix" that is used to map spillover effects from cuts in funding to particular parts of the non-profit research sector into specific industries.

Estimating induced industry R&D. To quantify the spillover effects, we used statistical estimates from the academic economics literature. A statistical analysis estimated that, for every 10% increase in university R&D spending within a state, firms within the state increased their own R&D spending by about 7%.[41] This estimate, however, implicitly holds constant university research in other states. Obviously, other states are going to be seeing their university research levels fall; indeed, we have assumed throughout that the Massachusetts reduction is proportional to the nationwide reduction. To correct for this, we utilized an inducement ratio of one-fourth of the effect found in the literature. That is, for each 1% reduction in university research relevant for a particular industry, we reduced that industry's R&D spending by .175%.

This inducement parameter was combined with the distribution of impacts by industry (the "weighting matrix") to estimate reductions in industry R&D funding generated by reductions in federal support for universities, hospitals and other non-profits. First, we took the (year by year) reductions in federal support shown in Figure TA-7 and allocated them across institutions and fields of science (for university research) based on historical NSF data. (This process is similar to the spending cuts that we created for broad industry groupings.) Then, we used the "weighting matrix" to transform cuts from discipline and year to industry and year. In other words, Figure TA-8 is used to flow reductions through to the affected industries. Figure TA-9 shows the effective reduction in university research

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[40] We were successful in assigning SIC codes to over 70% of the citing patents.

[41] Adam Jaffe, "Real Effects of Academic Research," *American Economic Review*, December 1989.

for each industry included in our analysis. By 2002, the non-profit research that most industries depend on has been reduced by about 35%. The actual research reduction in each industry was calculated by taking the percentage reduction in the university research allocated to that industry, and then applying 17.5% of this reduction to projected company-financed R&D spending in each industry. The resulting induced R&D expenditure changes are shown in Figure TA-10. The size of these numbers is determined by the combined effect of the overall scale of company-financed R&D in the industry in Massachusetts and the extent to which the industry was shown to depend on university and other non-profit research via its patent citations.

Supply / innovation effects. The reductions in federal non-profit research, federal industry research, and induced company-funded industry research will each have impacts in the form of a reduced flow of new commercial technology. We calculate these type of effects for all industries except the engineering and research industry, whose output in some sense is research. To estimate the size of these impacts, we utilized estimates from the economic literature on the rate of return to different forms of R&D. For the induced reduction in company-funded industry R&D, we used an estimate of the gross rate of return to private R&D of 40%, roughly the mid-point of published estimates that range from about 25% to 60%. For the impact of university and non-profit research, we used an estimate from the study cited above on the state-level impact of university research, combined with the assumed return on private R&D of 40%. Finally, for the reduction in federally funded industry research, we used an estimate that federally funded industry research has an effect on industry sales that is 35% as large as the effect of company-funded research; combined with our estimate of 40% for the rate of return to company-funded research this yields a return to federally funded industry research of 14%.[42]

[42] For a brief discussion of studies on the rate of return of R&D, see Gregory Tassey, "Technology and Economic Growth: Implications for Federal Policy," NIST, October 1995 at 15-18. For evidence on the rate of return on federally funded private research, see Zvi Griliches, "Productivity, R&D, and Basic Research at the Firm Level," *American Economic Review*, March 1986.

The economic studies imply that reductions in R&D reduce the growth rate of sales of the industry over time. Because R&D affects the growth rate, reductions have an effect that is cumulative over time. On the other hand, as time passes, the effect of old R&D diminishes because of obsolescence as new technology becomes more relevant. In order to capture this effect, we assumed that the impact of R&D erodes at a rate of 15% per year.

A final issue with the supply/innovation effects is the time lags that are likely to occur before reductions in research affect the rate at which new commercial technologies are introduced. Because next year's products and processes are likely to be based on the results of research from several years ago, reductions in research today will reduce the flow of new products and processes at some unknown future date. These lags are likely to be particularly significant with respect to the commercialization of university technologies. We have incorporated a lag of six years into our analysis, based on survey results.[43]

Thus while the direct as well as induced demand effects occur in the near term (concurrent with the budget cuts), the supply effects do not begin to impact the economy until 2002. When we combine the calculated impact of the three different sources of innovation effects, cumulate them over time and take account of obsolescence, the output reductions by industry in each year are as presented in Figure TA-11. The Figure shows that these effects are initially extremely small, less than one-tenth of a percent of baseline output in these industries. The effects grow over time, however, both because the reductions in research increase over time and also because they work via the growth rate of output.

Magnitude of induced demand and supply / innovation effects in REMI model. As with the direct demand effects, we estimate the overall effect on the Massachusetts economy by incorporating into the REMI model the

[43] The most detailed analysis of these lags has been done by Edwin Mansfield. His most recent estimates of the lag between university research and its commercial impacts vary from 5 to 9 years, with a mean of 6 years. See Mansfield (1996) "Industry-University R&D Linkages and Technological Innovation."

research spending reductions in Figure TA-10 and the output reductions in Figure TA-11.

Summary of Results

Figure TA-12 summarizes the overall effects on research in different sectors. For the non-profit sectors (medical, university and other), we looked only at federal support. These institutions experience a decline in overall research spending that is not surprising since federal support is so important. For industrial firms, we look at the net effect of both industrial research and federally funded research after subtracting off the direct cut in federal spending, the induced demand effect, and the supply/innovation effect. Our baseline assumes that industrial research grows at the rate of growth of sales in each industry and federal research grows according to the baseline described above. All industries except aerospace continue to increase their research funding, albeit at a slower rate.

The direct demand, induced demand, and supply/innovation effects are inputted into the REMI model which quantifies the overall effect of the spending reduction, including "multiplier" effects that occur as the reduced spending leads to lower income and hence further reduced spending by downstream firms and industries. The results for the declining spending and **constant spending scenarios** are summarized in Figures TA-13 and TA-14. Figures TA-15 and TA-16 provide a more detailed view of the sector by sector employment effects from the direct demand, induced demand, and supply/innovation effects under the declining spending scenario.

Figure TA-1

1993 Research Funding at Massachusetts Universities

(Thousands of Dollars)

Institution	Total	Federal	Industry	Own	State	Other
Massachusetts Institute of Technology*	$365,553	$267,414	$58,106	$8,139	$3,058	$28,836
Harvard University	257,207	181,969	9,319	14,610	358	50,951
University of Massachusetts (All Campuses)	144,765	74,444	12,752	37,462	10,119	9,988
Boston University	91,158	71,593	9,982	0	994	8,589
Woods Hole Oceanographic Institution	81,519	73,546	644	1,245	429	5,655
Tufts University	56,976	46,625	9,328	985	11	27
Brandeis University	36,213	21,825	0	4,520	120	9,748
Northeastern University	18,517	15,339	1,445	144	325	1,264
Worcester Polytechnic Institute	11,484	9,164	957	1,054	150	159
Boston College	10,731	8,151	286	1,060	75	1,159
Other**	16,747	10,144	688	3,448	0	2,467
Total	$1,090,870	$780,214	$103,507	$72,667	$15,639	$118,843

* Excludes Lincoln Labs

** Institutions with less than $10 million total funding.

Note: Data exclude 2-year, religious, teaching, and art institutions.
Sums may not be consistent throughout due to the use of multiple surveys.

Source: NSF

Figure TA-2
Massachusetts Hospital and Other Non-profit Research Support
(Thousands of Dollars)

Name of Institution	FY 1993 Federal Sponsored Research Obligations	FY 1993 Industry Sponsored Research Expenditures*	FY 1993 Other Sponsored Research Expenditures*
Hospitals			
Massachusetts General Hospital	$89,109	$42,398	$28,558
Brigham & Women's Hospital	86,394	19,006	14,948
Dana-Farber Cancer Institute	51,700	19,673	7,087
Children's Hospital, Boston	32,816	5,000	28,700
New England Medical Center	23,642	8,100	4,900
Beth Israel Hospital	18,524	2,261	13,526
New England Deaconess Hospital	13,977	11,114	0
McLean Hospital	10,511		
Mass Eye & Ear Infirmary	6,976		
University Hospital	6,645		
Hebrew Rehab Center	4,053		
St. Elizabeth's Hospital	3,004		
TOTAL	$347,351		
Research Laboratories			
MIT Lincoln Laboratories**	355,000		
Mitre Corporation	246,344		
Draper Laboratories	64,327		
TOTAL	$665,671		
Research Institutes and Other			
Whitehead Institute Biomed	15,895		
Worcester Foundation of Experimental Biology	8,661		
Center of Blood Research	8,066		
Joslin Diabetes Foundation	7,955		
Education Development Center	7,940		
Schepens Eye Research Institute	5,906		
Boston Biomedical Research	5,873		
Forsyth Dental Center	5,366		
EK Shriver Center Mental	5,353		
National Bureau of Economic Research	5,214		
Tech Education Research Center	5,076		
TOTAL	81,305		
Others	17,982		
TOTAL	$1,112,309		

* only available for institutions reporting to AUTM survey.
** from NSF expenditure data

Source: NSF; AUTM.

Figure TA-3

Industrial R&D by Source of Funds in Massachusetts

1991

(Millions of Dollars)

Industry	SIC Code	Total	Federal	Company
Food, Kindred and Tobacco Products	20,21	26	0	26
Textiles and Apparel	22,23	10-13	0-3	10
Lumber, Wood Products and Furniture	24,25	0	0	0
Paper and Allied Products	26	18	0	18
Chemicals and Drugs	28	238	1	237
Drugs and Medicines	283	52-53	0-1	52
Petroleum Refining and Extraction	13,29	0-60	0	0-60
Rubber Products	30	5-8	0-3	5
Stone, Clay and Glass Products	32	0-62	0-3	0-60
Primary Metals	33	43	1	42
Fabricated Metal Products	34	53	0	53
Machinery & Computers	35	2,048	21	2,027
Office, Computing, and Accounting Mach.	357	1899-192	0-21	1,899
Electrical and Electronic Equipment	36	1,533	583	950
Communication Equipment	368	768-828	457-517	311
Electronic Components	367	620	41	579
Transportation & Aerospace	37	518-578	352	166-226
Aircraft and Missiles	372,376	518	352	166
Professional and Scientific Instruments	38	479	7	472
Scientific and Mechanical Measuring Equip.	381-382	207-214	0-7	207
Optical, Surgical, Photographic and Other Inst.	383-387	265-272	0-7	265
Other Manufacturing Industries	27,31,39	17-20	0-3	17
Nonmanufacturing Industries	10-11,14-17,40-42,44-51,53-54,56,60,62-63,72-73,78,806-07,87	1,285	513	772
Total		6,335	1,480	4,855

Source: NSF/SRS

Figure TA-4

Funding by Agency to Massachusetts Performers of Research
(1993)

	DOD	HHS	Other Agencies
Universities	19%	41%	40%
Hospitals & Healthcare	1%	99%	0%
Other Non-Profits	87%	0%	13%
Industry	91%	4%	5%

Figure TA-5

Federal Research Spending Projections by Sector
Declining Spending and Constant Spending Scenarios

(Millions of Dollars)

Baseline Forecast of Federal Research Spending

	1995	1996	1997	1998	1999	2000	2001	2002
Hospitals & Healthcare	$551	$574	$607	$641	$677	$714	$752	$790
Education	$794	$822	$866	$912	$959	$1,008	$1,059	$1,110
Chemicals & Drugs	$1	$1	$1	$1	$1	$1	$1	$1
Machinery & Computers	$25	$25	$26	$27	$28	$29	$30	$31
Electrical & Electronic Equipment	$702	$705	$731	$757	$784	$811	$839	$868
Transportation & Aerospace	$424	$426	$441	$457	$473	$490	$507	$524
Professional & Scientific Instruments	$8	$8	$9	$9	$9	$10	$10	$10
Engineering & Research	$1,142	$1,148	$1,190	$1,234	$1,278	$1,323	$1,369	$1,417
TOTAL	**$3,647**	**$3,710**	**$3,872**	**$4,039**	**$4,210**	**$4,386**	**$4,567**	**$4,752**
TOTAL -- $1995	**$3,647**	**$3,579**	**$3,604**	**$3,628**	**$3,653**	**$3,677**	**$3,701**	**$3,723**

Total Federal Funding by Sector, Declining Spending Scenario

	1995	1996	1997	1998	1999	2000	2001	2002
Hospitals & Healthcare	$551	$577	$533	$533	$532	$532	$532	$532
Education	$794	$799	$694	$685	$677	$672	$670	$667
Chemicals & Drugs	$1	$1	$1	$1	$1	$1	$1	$1
Machinery & Computers	$25	$25	$23	$22	$22	$21	$21	$21
Electrical & Electronic Equipment	$702	$683	$642	$624	$610	$596	$584	$572
Transportation & Aerospace	$424	$412	$387	$376	$368	$360	$353	$345
Professional & Scientific Instruments	$8	$8	$8	$7	$7	$7	$7	$7
Engineering & Research	$1,142	$1,109	$1,035	$1,005	$982	$961	$941	$921
TOTAL	**$3,647**	**$3,614**	**$3,323**	**$3,254**	**$3,200**	**$3,152**	**$3,108**	**$3,066**
TOTAL -- $1995	**$3,647**	**$3,486**	**$3,093**	**$2,923**	**$2,777**	**$2,642**	**$2,519**	**$2,402**

Total Federal Funding by Sector, Constant Spending Scenario

	1995	1996	1997	1998	1999	2000	2001	2002
Hospitals & Healthcare	$551	$551	$551	$551	$551	$551	$551	$551
Education	$794	$794	$794	$794	$794	$794	$794	$794
Chemicals & Drugs	$1	$1	$1	$1	$1	$1	$1	$1
Machinery & Computers	$25	$25	$25	$25	$25	$25	$25	$25
Electrical & Electronic Equipment	$702	$702	$702	$702	$702	$702	$702	$702
Transportation & Aerospace	$424	$424	$424	$424	$424	$424	$424	$424
Professional & Scientific Instruments	$8	$8	$8	$8	$8	$8	$8	$8
Engineering & Research	$1,142	$1,142	$1,142	$1,142	$1,142	$1,142	$1,142	$1,142
TOTAL	**$3,647**	**$3,647**	**$3,647**	**$3,647**	**$3,647**	**$3,647**	**$3,647**	**$3,647**
TOTAL -- $1995	**$3,647**	**$3,518**	**$3,394**	**$3,276**	**$3,164**	**$3,057**	**$2,955**	**$2,857**

Source: ERG calculations using REMI model.

Figure TA-6

Baseline Projected Growth in Federal Spending in Massachusetts

	Nominal Expenditure Level Relative to 1995 Level		Inflation-Adjusted Expenditure Level Relative to 1995 Level	
	Military	Civilian	Military	Civilian
1995	1.00	1.00	1.00	1.00
1996	1.00	1.04	0.97	1.01
1997	1.03	1.10	0.96	1.03
1998	1.07	1.17	0.96	1.05
1999	1.10	1.23	0.96	1.07
2000	1.14	1.30	0.96	1.09
2001	1.18	1.37	0.95	1.11
2002	1.21	1.44	0.95	1.13

Source: Regional Economic Models, Inc.

Figure TA-7

Projected Federal Research Funding Cuts by Sector, Relative to Baseline

Declining Spending and Constant Spending Scenarios

(Millions of Dollars)

Total Federal Funding Cuts by Sector, Declining Spending Scenario

	1995	1996	1997	1998	1999	2000	2001	2002
Hospitals & Healthcare	$0	$3	-$74	-$109	-$145	-$181	-$220	-$258
Education	$0	-$23	-$172	-$227	-$282	-$336	-$389	-$443
Chemicals & Drugs	$0	$0	$0	$0	$0	$0	$0	-$1
Machinery & Computers	$0	-$1	-$3	-$5	-$6	-$8	-$9	-$11
Electric & Electronic Equipment	$0	-$22	-$89	-$134	-$174	-$215	-$255	-$296
Transportation & Aerospace	$0	-$13	-$54	-$81	-$105	-$130	-$154	-$179
Professional & Scientific Instruments	$0	$0	-$1	-$2	-$2	-$3	-$3	-$4
Miscellaneous Professional Services	$0	-$39	-$155	-$228	-$295	-$362	-$428	-$495
TOTAL	**$0**	**-$96**	**-$549**	**-$785**	**-$1,010**	**-$1,234**	**-$1,459**	**-$1,687**
TOTAL -- $1995	**$0**	**-$93**	**-$511**	**-$705**	**-$876**	**-$1,034**	**-$1,182**	**-$1,321**

Total Federal Funding Cuts by Sector, Constant Spending Scenario

	1995	1996	1997	1998	1999	2000	2001	2002
Hospitals & Healthcare	$0	-$23	-$56	-$90	-$126	-$163	-$201	-$240
Education	$0	-$28	-$72	-$118	-$165	-$214	-$265	-$316
Chemicals & Drugs	$0	$0	$0	$0	$0	$0	$0	$0
Machinery & Computers	$0	$0	-$1	-$2	-$3	-$4	-$5	-$6
Electric & Electronic Equipment	$0	-$3	-$29	-$55	-$82	-$109	-$137	-$166
Transportation & Aerospace	$0	-$2	-$18	-$33	-$50	-$66	-$83	-$100
Professional & Scientific Instruments	$0	$0	$0	-$1	-$1	-$1	-$2	-$2
Miscellaneous Professional Services	$0	-$6	-$49	-$92	-$136	-$181	-$227	-$275
TOTAL	**$0**	**-$63**	**-$225**	**-$392**	**-$563**	**-$739**	**-$920**	**-$1,105**
TOTAL -- $1995	**$0**	**-$61**	**-$209**	**-$352**	**-$489**	**-$620**	**-$746**	**-$866**

Source: ERG calculations using REMI model.

Figure TA-8

Linkages Between Massachusetts Universities, Hospitals, Other Non-Profits and Industry

Based on Industry Citations to Patents from Massachusetts Institutions

	Fraction of Citations to Patenting Entity by Industry							
Patenting Entity	Chemicals & Drugs	Machinery & Computers	Electric & Electronic Equipment	Transportation & Aerospace	Professional & Scientific Instruments	Engineering & Research	Other	TOTAL
Hospitals	49%	0%	2%	2%	21%	12%	14%	86%
Other Non-Profit	7%	25%	13%	28%	16%	4%	8%	92%
Lincoln Labs	1%	27%	22%	19%	17%	5%	9%	91%
University Departments								
Engineering	17%	12%	14%	13%	20%	5%	19%	81%
Physical Sciences	56%	3%	1%	5%	8%	7%	20%	80%
Geosciences	0%	14%	14%	29%	0%	0%	43%	57%
Math & Computer Sciences	0%	39%	22%	26%	3%	0%	10%	90%
Life Sciences	44%	5%	0%	5%	11%	5%	29%	71%
Other Science Depts.	14%	0%	5%	5%	14%	55%	9%	91%

Notes: Totals do not sum to 100% because only a subset of all citing industries is reported.
University department data is based on citations to MIT patents.

Figure TA-9

Decrease in Non-Profit Research Spending: Linkages Between Industry and Non-Profit Institutions

	1996	1997	1998	1999	2000	2001	2002
Chemicals & Drugs	-1%	-16%	-21%	-25%	-29%	-33%	-36%
Machinery & Computers	-4%	-16%	-22%	-26%	-30%	-34%	-38%
Electric & Electronic Equipment	-4%	-16%	-21%	-26%	-30%	-33%	-37%
Transportation & Aerospace	-4%	-17%	-22%	-27%	-31%	-35%	-38%
Scientific & Professional Instruments	-2%	-15%	-20%	-24%	-28%	-32%	-35%
Engineering & Research	-1%	-15%	-20%	-25%	-29%	-32%	-36%

Source: ERG calculations.

Figure TA-10

Cuts in Industry R&D Induced By Cuts to Universities, Hospitals, and Other Non-Profits

Declining Spending Scenario

(Millions of Dollars)

SIC	Industry	1996	1997	1998	1999	2000	2001	2002
28	Chemicals and Drugs	$0	-$9	-$13	-$17	-$21	-$25	-$29
35	Machinery & Computers	-$19	-$86	-$122	-$155	-$190	-$224	-$260
36	Electric & Electronic Equipment	-$8	-$39	-$55	-$71	-$88	-$105	-$122
37	Transportation and Aerospace	-$2	-$8	-$10	-$13	-$15	-$18	-$20
38	Professional & Scientific Instruments	-$2	-$18	-$25	-$32	-$40	-$47	-$55
87	Engineering & Research	-$2	-$29	-$40	-$52	-$65	-$77	-$91

Source: ERG calculations.

Figure TA-12

Levels of R&D Funding by Sector, 1996 - 2002

Declining Spending Scenario

(Millions of Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Medical *	$503	$536	$551	$577	$533	$533	$532	$532	$532	$532
Education *	$770	$781	$794	$799	$694	$685	$677	$672	$670	$667
Other Non-Profit *	$482	$447	$457	$443	$403	$386	$372	$359	$345	$332
Chemicals	$259	$278	$296	$315	$327	$346	$366	$386	$407	$428
Machinery	$2,230	$2,536	$2,735	$2,898	$2,990	$3,119	$3,257	$3,402	$3,555	$3,699
Electrical Equipment	$1,773	$1,845	$1,953	$2,009	$2,023	$2,076	$2,137	$2,201	$2,269	$2,325
Transportation Equipment	$674	$654	$669	$661	$639	$633	$630	$627	$625	$618
Professional and Scientific Instruments	$522	$589	$629	$662	$682	$711	$740	$771	$802	$833
Miscellaneous Professional Services	$1,562	$1,568	$1,637	$1,676	$1,681	$1,724	$1,774	$1,827	$1,885	$1,946

* Federal R&D Only

Figure TA-13

Summary of Impacts of Federal Research Spending Cuts on the Massachusetts Economy

Declining Spending Scenario

Source of Impact	1997 Gross State Product (Billions of 1995 Dollars)	1997 Employment (Thousands)	2002 Gross State Product (Billions of 1995 Dollars)	2002 Employment (Thousands)	2010 Gross State Product (Billions of 1995 Dollars)	2010 Employment (Thousands)
Reduction In Federal Support of Research at Universities and Other Non-profits						
Direct Demand Effect	-$0.440	-10.0	-$0.966	-21.5	-$0.647	-13.5
Induced Industry Research Demand Effect	-$0.200	-2.5	-$0.461	-5.1	-$0.306	-2.8
Supply/Innovation Effect	N/A	N/A	-$0.021	-0.2	-$2.708	-20.4
Subtotal - Universities and Other Non-profit R&D	-$0.640	-12.5	**-$1.448**	**-26.8**	**-$3.661**	**-36.7**
Reduction In Federal Support of Research In Industry						
Direct Demand Effect	-$0.277	-4.4	-$0.681	-10.2	-$0.440	-6.1
Supply/Innovation Effect	N/A	N/A	-$0.008	-0.1	-$0.668	-6.7
Subtotal - Industry R&D	-$0.277	-4.4	**-$0.689**	**-10.3**	**-$1.108**	**-12.8**
Overall Impact	-$0.917	-16.9	-$2.137	-37.1	-$4.769	-49.5

Source: ERG calculations using REMI model.

Figure TA-14

Summary of Impacts of Federal Research Spending Cuts on the Massachusetts Economy

Constant Spending Scenario

Source of Impact	1997 Gross State Product (Billions of 1995 Dollars)	1997 Employment (Thousands)	2002 Gross State Product (Billions of 1995 Dollars)	2002 Employment (Thousands)	2010 Gross State Product (Billions of 1995 Dollars)	2010 Employment (Thousands)
Reduction In Federal Support of Research at Universities and Other Non-profits						
Direct Demand Effect	-$0.208	-4.8	-$0.724	-16.1	-$0.475	-9.9
Induced Industry Research Demand Effect	-$0.079	-1.0	-$0.306	-3.5	-$0.200	-1.9
Supply/Innovation Effect	N/A	N/A	-$0.010	-0.1	-$1.452	-11.1
Subtotal - Universities and Other Non-profit R&D	-$0.287	-5.8	**-$1.040**	**-19.7**	**-$2.127**	**-22.9**
Reduction In Federal Support of Research In Industry						
Direct Demand Effect	-$0.089	-1.4	-$0.387	-5.8	-$0.245	-3.4
Supply/Innovation Effect	N/A	N/A	-$0.009	-0.1	-$0.670	-6.7
Subtotal - Industry R&D	-$0.089	-1.4	**-$0.396**	**-5.9**	**-$0.915**	**-10.1**
Overall Impact	-$0.376	-7.2	-$1.436	-25.6	-$3.042	-33.0

Source: ERG calculations using REMI model.

Figure TA-15

Employment Changes Due to Cuts in Federal Research Support

Direct Demand Effects

Declining Spending Scenario

(Thousands of Jobs)

	EMPLOYMENT EFFECTS		
	1997	2002	2010
Private Non-Farm Employment (Baseline Total)	**3248.2**	**3406.5**	**3613.8**
Change in Private Non-Farm Employment	**-14.4**	**-31.7**	**-19.6**
% Change in Private Non-Farm Employment	-0.4%	-0.9%	-0.5%
Change in Employment by Selected Sectors			
Education	-3.8	-7.7	-5.0
Hospitals & Healthcare	-2.1	-5.4	-3.6
Electrical & Electronic Equipment	-0.3	-0.7	-0.3
Transportation and Aerospace	-0.3	-0.7	-0.5
Engineering & Research	-2.9	-7.2	-4.9
Retail	-1.0	-2.1	-1.2
Misc. Business Services	-0.7	-1.4	-0.8
Construction	-0.7	-1.3	-0.4
Real Estate	-0.2	-0.4	-0.2
Eating & Drinking	-0.5	-1.2	-0.8

Source: ERG calculations using REMI model.

Figure TA-16

Employment Changes Due to Cuts in Federal Research Support

Supply and Induced Demand Effects

Declining Spending Scenario

(Thousands of Jobs)

	INDUCED DEMAND		SUPPLY	
	2002	2010	2002	2010
Private Non-Farm Employment (Baseline Total)	**3406.5**	**3613.8**	**3406.5**	**3613.8**
Change in Private Non-Farm Employment	**-5.1**	**-2.8**	**-0.3**	**-27.1**
% Change in Private Non-Farm Employment	-0.1%	-0.1%	0.0%	-0.8%
Change in Employment by Selected Sectors				
Chemicals and Drugs	-0.1	0.0	0.0	-0.4
Machinery & Computers	-0.6	-0.3	0.0	-3.2
Electrical & Electronic Equipment	-0.3	-0.2	0.0	-2.6
Transportation & Aerospace	-0.1	-0.1	0.0	-1.8
Professional & Scientific Instruments	-0.2	-0.1	0.0	-1.2
Engineering and Research	-1.2	-0.8	0.0	-1.6
Retail	-0.4	-0.2	0.0	-2.4
Miscellaneous Business Services	-0.4	-0.2	0.0	-2.5
Construction	-0.3	-0.1	0.0	-1.6

Source: ERG calculations using REMI model.