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MEDICAL DEVICES:

Supporting the Massachusetts Economy

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For the Massachusetts Medical Device Industry Council

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Introduction

The Massachusetts medical-device industry is important beyond its size, from several perspectives. As an economic contributor, the development and marketing of medical devices have a "ripple effect" on both the state's economy and its population's well-being.

- The industry requires a highly educated workforce and cutting-edge technical components.
- The industry's impact extends beyond the employment and earnings of medical-device workers: every hundred jobs is associated with another 79 jobs in Massachusetts, and every dollar of medical-device output is associated with an additional 45 cents of outputs from Massachusetts firms.
- Each medical device is aimed at a specific medical need, so manufacturers, researchers, and medical staffs often work collaboratively to ensure that the need is in fact met by the device, thus ensuring high-quality patient care.

Furthermore, even during the recent downturn of the economy, the medical-device industry in Massachusetts posted modest growth.

In the national context, Massachusetts is a key competitor, and—because of the industry's inherent importance, both financially and socially—it is well worth developing and adopting public policies to help keep Massachusetts in that position.

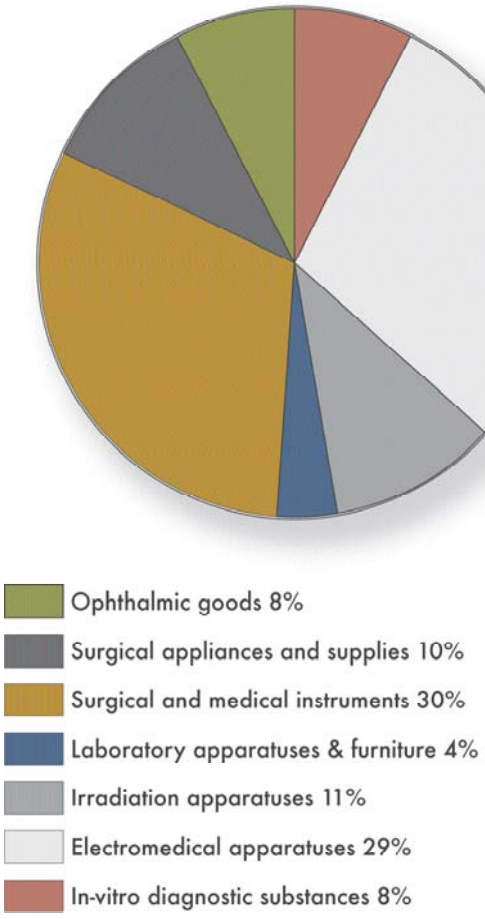
In 2001, the lead author wrote *The Medical Device Industry in Massachusetts* as an introduction to this key Massachusetts industry. Now, with *Medical Devices: Supporting the Massachusetts Economy*, the current authors expand and deepen our understanding of the continuing significance, to the nation as well as the Commonwealth, of this sometimes-overlooked feature in Massachusetts's economic landscape.

BASIC CHARACTERISTICS OF MEDICAL DEVICES IN MASSACHUSETTS

According to the U.S. Census Bureau's County Business Patterns, in 2001 the Massachusetts medical-device sector consisted of 221 establishments with 20,370 payroll employees in March of that year, and a total payroll for the year of $1.16 billion. These suggest that the average annual wage or salary per employee in 2001 was $57,200, and that the average establishment employs 92 workers.

Medical devices as a category comprises seven detailed NAICS industries, or subsectors.[1] Figure 1 shows the percentage of workers employed in each subsector in Massachusetts. The two largest subsectors are *surgical and medical instruments* and *electromedical apparatuses*. In terms of employment or payroll, the two subsectors are nearly equal in size, together accounting for just over 60 percent of employment and payroll. The sizes of establishments in these two sectors are quite different, however. The average surgical and medical-instrument plant employs 77 workers, whereas the average electromedical facility employs 197.

Figure 1. Medical-Device Employment in Massachusetts, 2001, By Industry



In terms of overall economic activity, the three next-largest subsectors, *irradiation apparatuses*, *surgical appliances and supplies*, and *in-vitro diagnostic substances*, are of roughly equal size, together accounting for nearly 30 percent of employment and just over 30 percent of payroll. Ophthalmic goods and laboratory apparatuses and furniture are the two smallest subsectors, comprising 11 percent of employment and 8 percent of payroll. Laboratory apparatuses and furniture are typically produced in the smallest establishments, employing on average 33 persons.

Average annual earnings in 2001 varied significantly between the detailed sectors, from $73,400 in *in-vitro diagnostic substances* to $35,100 in *ophthalmic goods*. Among the two largest subsectors, *electromedical apparatuses* workers earned on average $62,200, about 9 percent above the medical-device average, while *surgical- and medical-instruments* workers earned $54,900, 4 percent below the medical-device average.

THE ECONOMIC IMPACT OF MEDICAL DEVICES ON THE MASSACHUSETTS ECONOMY

The most recently available data on shipments of the medical-device industry is from the 1997 Economic Census, which reports shipments of nearly $4 billion from Massachusetts medical-device establishments in 1997 (U.S. Department of Commerce 2000).[2] Although shipments from the next (2002) Economic Census will not be available for a couple of years, an estimate can be derived from trends in state payrolls from the County Business Patterns and Quarterly Census of Employment and Wages (QCEW, also known as ES-202) reports.[3] These sources indicate that the wage and salary payroll in the industry grew from $989 million in 1997 to $1,242 million in 2002, a growth of 25.5 percent.[4] Since the shipments-to-payroll ratio is stable over time, shipments grew at about the same rate, and so were approximately $5 billion in 2002.

This economic activity impacts the Massachusetts economy in two basic ways: through the industry's exports, and through its linkages with other industries in the state.

Like other manufacturing industries and several knowledge industry–service sectors, the medical-device industry exports products to other states and countries, drawing money into the state in the form of wages and salaries, and in the form of returns to local owners and suppliers of capital to the industry. According to the 1998 REMI input/output model of the Massachusetts economy, slightly more than half of the medical device output produced in Massachusetts is exported to other states

and countries.[5] Based on total shipments of $5 billion from Massachusetts establishments, this means that approximately $2.5 billion was exported to destinations outside the state.

Making medical devices requires inputs from other manufacturers and service providers. These linkages to other sectors means that the impact of the medical-device industry extends beyond the employment and earnings of medical-device workers. The 1998 REMI model for the Massachusetts economy estimates that, for every dollar of output in the industry, 45 cents' worth of materials and services are purchased from other industries. Of this 45 cents, 22 cents are from suppliers located in Massachusetts. The chief suppliers to the medical-device industry consist of electronics, plastics, and metal manufacturers, and wholesale trade-, transportation-, and communication-service providers. These in-state suppliers likewise have linkages with other Massachusetts providers of goods and services. Also, medical-device workers' spending has economic impacts on the state's economy, as does the spending of workers in other industries that supply the medical-device industry.

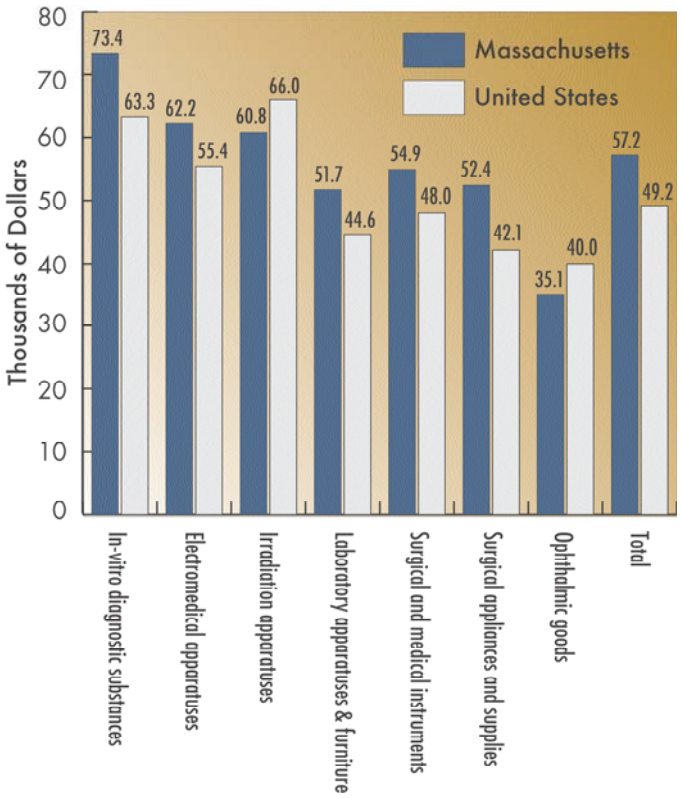
Using REMI's input/output model of the state's economy, the economic effect of these direct and indirect linkages can be summarized in two multipliers on medical-device output (shipments) and employment. The output multiplier of 1.45 signifies that every dollar of medical-device output is associated with, or connected to, an additional 45 cents of output from Massachusetts firms. The employment multiplier of 1.79 means that every hundred jobs in medical-device firms is associated with another 79 jobs in Massachusetts. Applying these multipliers to the 2002 estimates of shipments and jobs in medical devices, the total impact of the medical-device industry on the Massachusetts economy in 2002 was $7.3 billion and 36,000 jobs.

A COMPARISON WITH THE INDUSTRY NATIONALLY

How do these basic characteristics in Massachusetts compare to the medical-device sector nationally?

Perhaps most significantly, medical-device workers in Massachusetts earn substantially more than their counterparts in the United States as a whole (see figure 2). The average annual earnings in Massachusetts, $57,200 in 2001, were 16.3 percent greater than the average of all U.S. medical-device workers, $49,200. This difference is only partially explained by differences in the mix of detailed industries between Massachusetts and the nation. It appears to be primarily due to higher productivity of

Figure 2. Annual Wages and Salaries, by Industry, 2001



Massachusetts workers, which in turn is related mainly to higher levels of educational attainment. In five of the seven subsectors, Massachusetts workers earned between 12.3 percent and 24.7 percent more than the average U.S. worker. Massachusetts wages were lower in two subsectors: *irradiation apparatuses*, where the Massachusetts annual average earnings of $60,800 were 7.8 percent below the U.S. average of $66,000, and *ophthalmic goods*, where the Massachusetts annual average earnings of $35,100 were 12.2 percent below the U.S. average of $40,000.

In terms of the mix of industries, the major difference between the Massachusetts and U.S. medical-device sector is the relative specialization of Massachusetts in *electromedical apparatuses* and *irradiation apparatuses*, and the relatively smaller presence in Massachusetts of *surgical appliances and supplies* producers. These differences partially explain the higher average pay and productivity in Massachusetts, as the former sectors have above-average industry pay—and by implication, productivity—and the latter sector has below-average industry pay. These differences are also consistent with the state's comparative advantage in computers and semiconductors.

Finally, the medical-device industry is more concentrated in Massachusetts than in the United States as a whole,

meaning that it comprises a larger part of the state's economy than it does in the national economy. In 2001, of every thousand workers in Massachusetts, 6.1 were employed in medical devices, while of every thousand workers in the United States as a whole, 2.6 were employed in medical devices. This means that the "location quotient" for Massachusetts, a measure of the relative geographic density of the industry in Massachusetts, was 2.3 in 2001. In other words, the proportion of the workforce engaged in producing medical devices in Massachusetts was 2.3 times that of the United States as a whole.

COMPETITOR STATES AND RANKINGS

Besides Massachusetts, what other states are important producers of medical devices? And how does Massachusetts compare in terms of size or concentration? These questions are important for several reasons. First, because the medical-device industry provides jobs that pay significantly more than the average job, and jobs that are relatively stable in terms of employment security, and therefore households and state economies benefit from the presence of the industry. Second, the industry exports more than half of its output to other states and countries, therefore drawing income into the state from around the country and world. Third, since the long-term growth prospects of the industry are excellent, driven by rising incomes and life expectancy worldwide, states "compete" for the growth in capacity in the industry and the associated jobs and incomes that such growth provides. That competition need not be overt, since new or expanding firms tend to locate where the existing capacity is present. After all, the current geographic concentrations of the industry reflect existing and past locational advantages. However, conditions related to locational advantage change, and may be affected by government policies, particularly those at the state level. Therefore, it is important to identify the key state players.

Both size and concentration are important in identifying the key competitor states. Size is important because of agglomeration economies, particularly the presence of hospitals, universities, metal-fabrication and plastics industries, and a large pool of skilled and educated workers. Concentration, that is, the size of the industry relative to the population, is also an important aspect of agglomeration, because, given adequate absolute size, it is indicative of sufficient technological know-how and capacity specific to that industry. Table 1 shows both these aspects.

Table 1. Rankings of Top Five Medical-Device States by Production Characteristics in 2001

	Per Capita			Absolute	
	Employment	Annual Payroll		Employment	Annual Payroll
1	Minnesota	Minnesota	1	California	California
2	Utah	Massachusetts	2	Illinois	Illinois
3	Massachusetts	Utah	3	Minnesota	Massachusetts
4	Nebraska	Nebraska	4	Florida	Minnesota
5	Illinois	Illinois	5	Massachusetts	Florida

The County Business Patterns data for 2001 contain two relevant criteria for comparison of the size of the medical-device sector between states: employment and payroll. By dividing by each state's population, these two measures can also be expressed in per-capita terms. One simple way to identify the key states is to note which are the largest using these criteria.

In terms of absolute size, the key states are California, Illinois, Minnesota, Massachusetts, and Florida. California is by far dominant in terms of size, with 63,600 employees and a payroll of $3.5 billion in 2001. The next-largest state in absolute size is Illinois, with 25,700 employees and a payroll of $1.4 billion in 2001. Employment and payroll in each of the three remaining states—Minnesota, Massachusetts, and Florida—range between 20,400 and 21,400, and $0.9 billion and $1.2 billion.

In terms of per-capita size, Minnesota is the clear leader, with 4.4 medical-device jobs per thousand population and $220 medical-device payroll per person. Massachusetts and Utah vie for second, with 3.2 and 3.6 jobs per thousand population, respectively, and $183 and $160 payroll per person, respectively. Nebraska and Illinois are the fourth- and fifth-largest states in per-capita terms. California is out of the top five in per-capita size simply because it is such a large and diverse state, with a population of nearly 34 million in 2001. California had 1.9 medical-device jobs per thousand population, and $105 medical-device payroll per person.

There is no one right way to combine these four measures—employment and payroll by absolute and per-capita size—into a single rank score, but one simple way is to assign a rank score to each of the four combinations, and then to form each state's total score as the sum of its rank scores.[6] Using such a simple scheme, Massachusetts ranks second, behind Minnesota and before California and

Illinois (tied for third and fourth), and Utah, Nebraska, and Florida. One shouldn't pay much attention to the particular order here. Utah and Nebraska rank high because, even though their medical-device sectors are small, they are very small states. The serious competitors to Massachusetts are thus California, Minnesota, Illinois, and Florida. Also, one should look to states or metropolitan areas that have a combination of hospitals, universities, and large pools of highly educated workers as future competitors, even if they currently have a relatively small medical-device presence.

DEMOGRAPHIC CHARACTERISTICS OF THE WORKFORCE FOR THE MEDICAL-DEVICE INDUSTRY

Who works in the medical-device industry, and what are the demographic and economic characteristics—sex, race and ethnicity, occupation, educational attainment, and earnings—of its workforce? How do the characteristics of medical-device workers differ from workers in other manufacturing industries, and from the workforce in general? Also, are Massachusetts medical-device workers in this industry different from medical-device workers in the rest of the country, and if so, in what ways?

The 2000 Decennial Census of the Population is the best source of information for answering these questions. The analysis in this section is based on the Census's Public-Use Microdata Samples (PUMS), a 5 percent random sample of the U.S. population (U.S. Census Bureau 2000). Demographic information from the PUMS reflects the characteristics of the population as of March 2000, except for earnings, weeks, and hours worked, which refer to the interviewees' work experience during the prior year, that is, for calendar year 1999. Individuals were included in this analysis if they worked in the NAICS industry sector 3391, titled "Medical Instruments." This is the closest match to the medical-device industry as it is defined for this report. The NAICS 3391 definition includes *surgical and medical instruments*, *surgical appliances and supplies*, *ophthalmic goods*, and *laboratory apparatuses and furniture*, which together comprise more than half of the employment in the medical-device industry. It excludes *electromedical and electrotherapeutic apparatuses*, *irradiation apparatuses*, and *in-vitro diagnostic substances*, which are parts of other NAICS industry classifications; also, it includes *dental equipment and supplies*, a category that is not part of the medical-device industry as defined for this report. Nevertheless, the characteristics of the workers excluded from this analysis are likely to be very similar to those who are included. In the analysis presented here, the demographic and economic characteristics of Massachusetts residents who worked in medical instruments are compared to Massachusetts workers in other manufacturing industries, to the Massachusetts workforce as a whole, and to medical-instrument workers in the United States as a whole.

Age and Sex

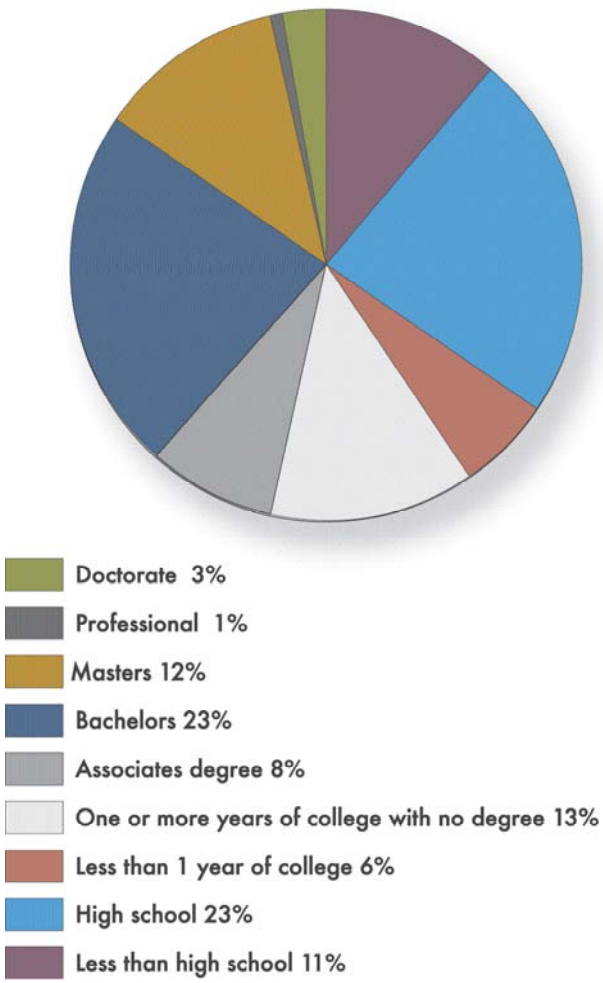
According to the Census, the median age of Massachusetts medical-instrument workers is 41 years old, with half of workers (the 25th–75th percentile range) between the ages of 33 and 50. Slightly over half of these workers, 54.7 percent, are men. These basic demographic characteristics are very similar to the U.S. medical-instrument workforce as a whole. The U.S. medical-instrument worker is just slightly younger, and somewhat less likely to be male. The median age of the U.S. medical-instrument worker is 40, with half between the ages of 32 and 48. Again, slightly over half, or 52.5 percent, are men. In terms of age, workers in this industry are representative of all manufacturing workers, but are slightly older than the workforce as a whole. The median age of all Massachusetts workers is 39, with half between the ages of 29 and 49.

In terms of gender, medical-instrument workers in Massachusetts are more representative of the workforce as a whole than of other manufacturing industries. In medical instruments, 45.3 percent are women, nearly the same proportion as in the state's workforce as a whole—49.1 percent. But only 32.9 percent of all manufacturing workers in Massachusetts are women.

Race and Ethnicity

The race and ethnic composition of the workforce in Massachusetts is different than that of the nation as a whole, with proportionately fewer black and Hispanic workers. The upshot is that 80.2 percent of the Massachusetts workforce in medical instruments is white non-Hispanic, compared to 71.4 percent nationwide. In the industry, only 2.6 percent of Massachusetts workers are black, and 6.5 percent Hispanic, compared to 6.3 percent and 11.7 percent, respectively, in the U.S. medical-instrument workforce. These Massachusetts–U.S. differences reflect the fact that the Massachusetts population is more white than is the United States as a whole. In Massachusetts, Asian workers comprise the largest nonwhite group, making up 8.2 percent of the medical-instrument workforce. In the United States as a whole, Asians comprise 8.5 percent of the industry.

Figure 3. Educational Attainment, Medical-Equipment Workers, Massachusetts, 2000



Within Massachusetts, the race and ethnic composition of the medical instrument workforce is somewhat different from other Massachusetts manufacturing workers, and from other Massachusetts workers as a whole. First, there are somewhat more minorities. While white non-Hispanics comprise 80.2 percent of the medical-instrument workforce, they comprise 82.0 percent of the manufacturing workforce and 83.8 percent of all Massachusetts workers. Most of this difference is accounted for by Asians, who account for 8.2 percent of medical-instrument workers versus 5.4 percent of manufacturing workers and 3.7 percent of all Massachusetts workers. The proportion of workers who are black is the same in medical instruments as in all manufacturing, 2.6 percent, but their representation among all jobs in the state is higher, at 4.5 percent of the workforce. There are proportionately more Hispanic workers in medical instruments than in all jobs, 6.5 percent versus 5.5 percent, but fewer than in manufacturing as a whole, 7.5 percent.

Education

The Massachusetts medical-instrument workforce (see figure 3) is a highly educated workforce in a highly educated state. Almost two-thirds of such workers—65.4 percent—have at least some college education, versus 60.5 percent of all U.S. medical-instrument workers. The Massachusetts–U.S. educational gap is even greater for those with a bachelor's or higher degree: 38.4 percent of Massachusetts medical-instrument workers versus 28.2 percent nationwide (see figure 4). This educational advantage is associated with a production technology that utilizes a more highly skilled occupation mix, higher productivity per worker, higher pay, and, undoubtedly, a product mix geared more to the development of new and leading-edge products, than the U.S. industry as a whole. The concentration of Ph.D.s in the Massachusetts medical-instrument workforce, at 2.8 percent, is over twice that of the U.S. industry as a whole.

Massachusetts medical-instrument workers are also more highly educated than their state counterparts both inside and outside of manufacturing. The proportion of the medical-instrument workforce with a bachelor's or higher degree is 38.4 percent, compared to 27.0 percent in all manufacturing, and 35.2 percent in all jobs.

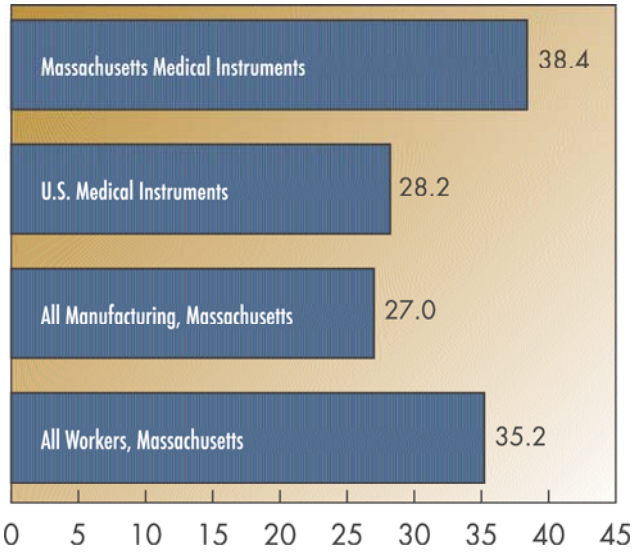
The educational advantage of the medical-instrument sector in Massachusetts does not exist in isolation from the rest of the state's economy. Indeed, Massachusetts has a higher proportion of its residents with a BA, 33.2 percent, than any other state in the nation. In contrast, 20.4 percent of U.S. residents have a BA degree.[7] In

combination with an exceptional environment regarding university and hospital research, and an ample number of custom metal and plastics producers, the large pool of highly educated workers in the Boston metropolitan area has given the state unique advantages in developing new devices.

Occupation

The occupational distribution of medical-instrument workers is typical of manufacturing in that a much higher proportion of the workforce is in production and related occupations than in nonmanufacturing sectors

Figure 4. Workers with a BA or Higher Educational Attainment, 2000 (Percent)



Source: U.S. Census Bureau 2000b

like services. However, a smaller percentage of workers in Massachusetts medical-instrument firms are engaged in these production-related occupations than in manufacturing as a whole, and than in medical-instrument firms outside of Massachusetts. While 47.6 percent of Massachusetts manufacturing workers, and 46.6 percent of U.S. medical-instrument workers, are engaged in production-related occupations, only 37.1 percent of Massachusetts medical-instrument workers are.

Employment in Massachusetts medical-instrument firms is concentrated at the upper end, in executive, administrative, managerial, professional specialty, and technical occupations; 44.7 percent of such firms' workers are engaged in these occupations, versus 33.6 percent for U.S. medical-instrument firms, and 34.1 percent of all manufacturing workers in Massachusetts. The bulk of these upper-tier Massachusetts medical-instrument workers are in management occupations (15.5 percent of workers) and in engineering occupations (12.1 percent of workers).

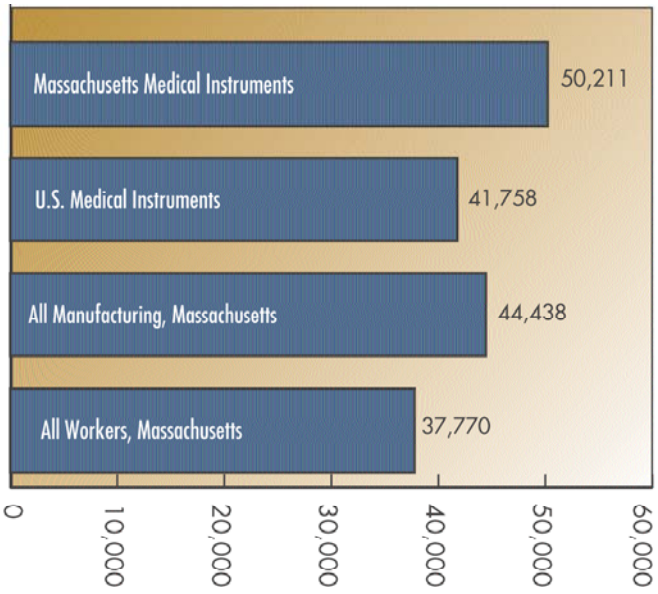
While only 4.6 percent of Massachusetts medical-instrument workers are in sales occupations, a slightly higher proportion than in all Massachusetts manufacturing (4.3 percent), sales jobs in medical devices, and in manufacturing in general, cannot be compared with the broad sales category for all workers, which makes up 10.8 percent of all jobs in the state. The majority of these latter jobs are in retail sales establishments and are quite different in both character and skill from sales jobs in manufacturing.

The proportion of Massachusetts medical-instrument workers in administrative support occupations, 13.1 percent, is about the same as in manufacturing overall (12.7 percent), and less than in the Massachusetts economy as a whole (16.2 percent). Not surprisingly, the medical-instrument industry, like manufacturing, employs very few persons in service occupations.

Earnings

Given the industry's higher level of educational attainment, it is not surprising that earnings are higher in medical instruments than in manufacturing or the economy as a whole. Median annual earnings of Massachusetts medical-instrument workers in 1999 was $39,400. Mean earnings was higher, at $50,211. (Mean earnings among any group of workers is typically higher than median earnings because of the influence of high salaries on the mean.) Half of workers earned between $23,000 and $60,000 (the 25th–75th percentile range). Ten percent earned $90,000 or more, and 5 percent earned $125,000 or more.

Figure 5. Mean Annual Earnings, 1999 (Dollars)



Source: U.S. Census Bureau 2000b

Technology Transfer and Product Development in the Medical-Device Industry

Technology transfer is a process in which one partner transfers knowledge and know-how to another who has capability to develop it further. Developing an idea into a commercialized product is particularly complex, usually involving multiple stages and contributors with a variety of skills and expertise along the way.

Since the passage of the Bayh–Dole Act in 1981, research institutions have had the right to retain intellectual property rights to inventions created by their employees with use of federal funds and accordingly, the right to transfer, through licensing, the rights to these inventions to third parties in exchange for financial consideration.

Typically, ideas that are considered to have commercial merit and that are developed within an institution of higher education are subject to the intellectual-property policies of the particular institution. Most sizable research institutions employ technology-transfer professionals to manage this process and to work to develop partnerships with commercial entities that are designed to result in products and produce revenues for the institution. These partnerships are one major way that private firms gain access to the cutting-edge research produced by such institutions.

Once an agreement has been reached between the research institution and the private firm, the firm engages in additional applied research, frequently in cooperation with the research institution, to develop the invention into a product which is then tested and evaluated by federal regulators and approved for sale, marketing, and distribution.

A series of interviews conducted with Massachusetts-based technology-transfer professionals and representatives of some of the Commonwealth's leading medical-device firms revealed that the transformation of ideas into products in the medical-device industry presents research institutions and public policy makers and the industry with a unique set of challenges.

Specifically, unlike many other areas of cutting-edge technology, in the medical-device industry:

- New advances are frequently developed by practicing physicians in clinical settings rather than by research scientists in university or corporate laboratories. Many research institutions have conflict-of-interest rules that prevent inventors who have a financial stake in a particular innovation from participating in the clinical trials of the potential new product. For many of these innovative clinicians, the cost of not being the first practitioner to utilize their new tool or technique is high indeed. This can make it more difficult to come to licensing and royalty agreements and can significantly delay the process of technology transfer and commercialization.
- Many medical-device inventions involve incremental technical improvements to an existing product. This can add a good deal of complexity to the process of licensing and determination of its value, which—again—can significantly delay the process of technology transfer and commercialization.
- Medical devices are usually quite specialized in nature and typically attend to a very specific need or problem in a specialized medical field and thus target a small market. Accordingly, the vast majority of medical devices bring in royalties that rarely exceed $250,000. Given that the legal and other professional costs associated with patenting and commercialization activities often exceed this amount—and that technology-transfer professionals often have other inventions with higher revenue potential—medical device–related disclosures often find themselves at the bottom of a very large pile of disclosures on a very busy tech-transfer professional's desk.

Despite these significant obstacles, in many respects the process of commercializing medical device–related technologies works quite well in Massachusetts, as evidenced by patents trends discussed in this report. Many useful ideas would never come to fruition if it were not for the existence of innovative technology-transfer and commercialization programs whose function is to build bridges between medical practitioners, funding organizations, research universities, and manufacturing firms.

Organizations such as CIMIT in Cambridge, The WPI Bioengineering Institute in Worcester, and BETA in Springfield are based near research universities and major medical centers. Others, such as the technology-transfer and licensing offices at MIT, Boston University, the University of Massachusetts, and Massachusetts General Hospital, are located within the research universities or medical centers themselves. In several instances these organizations have developed highly creative solutions to the challenges just outlined. They can provide immediate support for those medical professionals and researchers who need help patenting their ideas, finding money, and contacting experts to assist in product research and development.

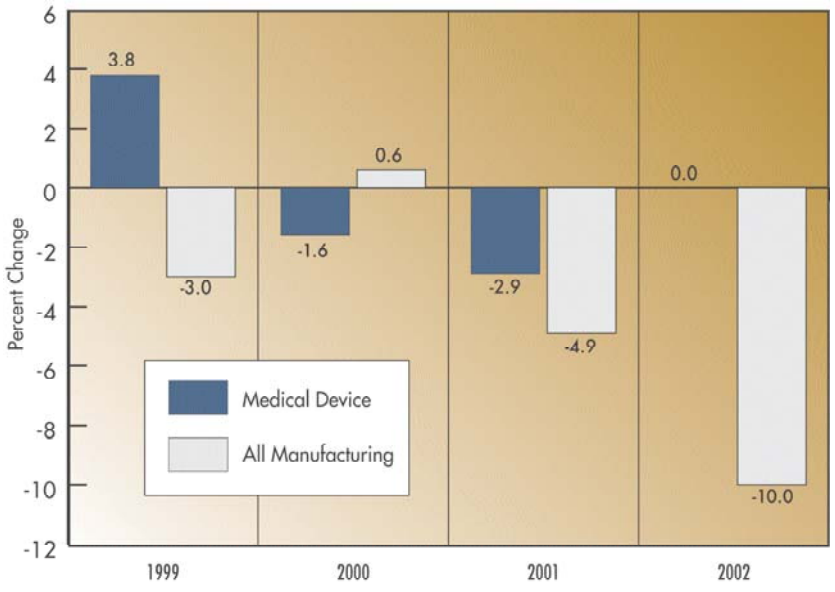
The somewhat unpredictable nature of technology transfer is not a drawback in an area saturated with the resources needed to make it happen. Massachusetts is fortunate to have an abundance of research medical universities, clinical and research physicians, venture-capital firms, medical-device manufacturers, and related firms whose expertise includes plastics, metalworking, and precise manufacturing. This creates an ideal environment to make contacts, share ideas, form partnerships, and perhaps develop a prototype. Technology-transfer organizations play a critical role in nurturing this environment.

These earnings are higher than those of manufacturing workers, or of Massachusetts workers in general. Median and mean earnings of Massachusetts manufacturing workers in 1999 were $34,500 and $44,438, respectively; median and mean earnings for all Massachusetts workers were $28,500 and $37,770, respectively.

Pay in manufacturing in general, and also in medical instruments, tends to be higher than in nonmanufacturing—regardless of educational level. These pay premiums probably reflect the value of specific job training for those with a high-school education or less, and higher market valuations for college or advanced degrees related to medical-device research and development, such as engineering, science, or medical degrees.

Massachusetts medical-instrument workers also earned more than their counterparts nationally, as is shown in figure 5. Median earnings for all U.S. medical-instrument workers were $30,000, and mean earnings were $41,758. These were roughly $9,000 below those of Massachusetts workers. Approximately half of this difference is explained by the higher educational attainment of Massachusetts workers. However, even accounting for differences in educational attainment, and other demographic differences between Massachusetts workers and their counterparts in the rest of the country, earnings in Massachusetts are still 12 percent higher.[8] What accounts for this difference? It may be due to the higher cost of living in Massachusetts, particularly housing costs, for which Massachusetts workers get compensated with higher salaries. However, since the industry sells its products in a national and international competitive market, there is little scope for employers to pay extra compensation to their workers for any reason. This means that much of the earnings premium of Massachusetts workers is probably related to higher productivity, even after accounting for higher educational attainment.

Figure 6. Employment Growth from Prior Year, Massachusetts (Percent)



TRENDS

What are the major trends in the medical-device industry, in terms of employment, payroll, productivity, and industry mix? To answer these questions, information from the County Business Patterns from 1998 through 2001 is supplemented with employment and payroll from the unemployment insurance system data on employment and payroll for 2001 and 2002. The latter series were used to grow the CBP data through 2002.

Most importantly, the medical-device industry was a stabilizing influence on Massachusetts's economy during the recession of 2001–2002. From 1998 through 2002, total payroll employment (annual average employment) in Massachusetts grew at an annual rate of 0.6 percent, while in medical devices, it declined at an annual rate of 0.2 percent. This is actually an impressive performance, since medical devices is a manufacturing industry. In all of manufacturing, employment in Massachusetts declined during this time at an annual rate of 4.4 percent (see figure 6).

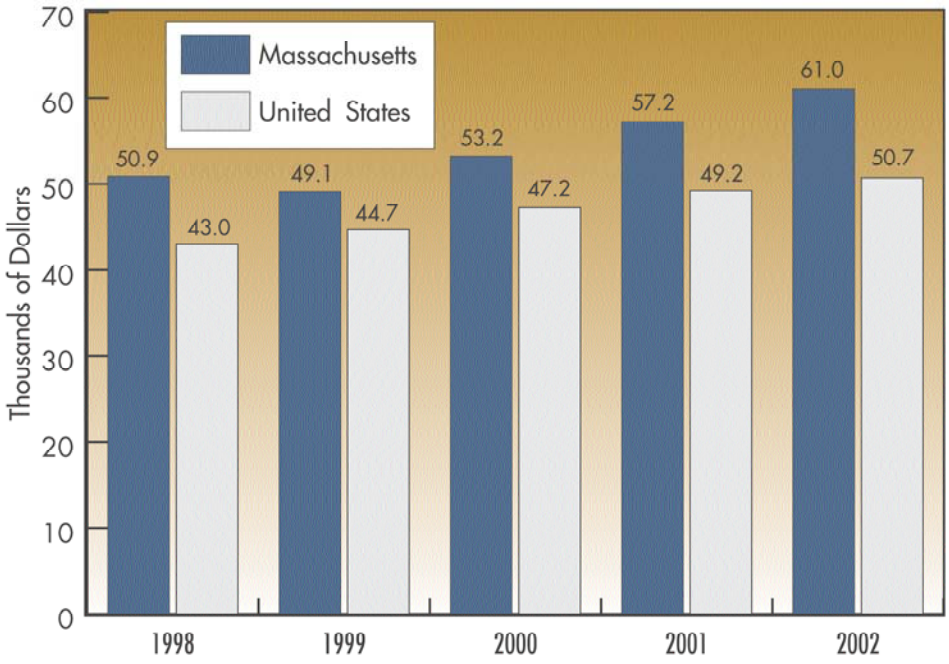
Because of productivity, payroll may be a better indicator of the industry's growth. During this same 1998–2002 period, average annual payroll growth in medical devices was 4.4 percent.

During this time, the U.S. medical-device sector was experiencing similar trends. U.S. medical-device employment grew at the rate of 0.1 percent annually, a slightly better performance than in Massachusetts. However, payroll growth nationally fell just short of that in Massachusetts, at a 4.3 percent annualized rate. In terms of payroll per employee, an indicator of productivity growth, the industry in Massachusetts surpassed that of the nation, as shown in figure 7.

In Massachusetts, average annual wages and salaries grew from $50,900 in 1998 to $61,000 in 2002, a 4.6 percent annualized rate of growth. In the United States, average annual wages and salaries grew from $43,000 in 1998 to $50,700 in 2002, a 4.2 percent annualized rate of growth. A corollary of this, of course, is that the gap between Massachusetts and U.S. wages grew slightly. The premium in Massachusetts grew from 18.4 percent in 1998 to 20.3 percent in 2002.

Part of the relatively greater growth in wages—and, by implication, productivity—in Massachusetts was due to a change in industry mix. The relatively well-paid *electromedical apparatus* manufacturing grew by 34 percent in terms of employment, and by 23 percent in terms of payroll in Massachusetts during this period, while in the United States, employment declined by 6 percent and payroll grew by only 2 percent. At the same time, the relatively lower-paid *laboratory apparatus and furniture* sector declined in Massachusetts, but grew nationwide. Payroll in the highly paid sector *in-vitro diagnostic substances* grew substantially in both Massachusetts and the United States, by 39 percent and 26 percent, respectively, although employment declined by 3 percent in this sector in Massachusetts, while it grew by 11 percent in the United States.

Figure 7. Annual Earnings in Medical Devices, 1998-2002



EXPORTS

Medical Devices as a Percent of Total Exports

The medical-device industry is one of the major sources of exports from the state of Massachusetts.[9] In 2003, 10 percent of all exports from Massachusetts were from the medical-devices cluster. Over the period 2001–2003, the industry's share increased from 7.7 percent to 10.0 percent of total exports, a 36.9 percent increase (see table 2).

The proportion of medical-device exports to total exports in the United States is lower than in Massachusetts. In 2003 only 2.5 percent of U.S. exports came from the medical-device industry.

Table 2. Total Exports and Medical-Device Exports, Massachusetts and United States, 2001–2003 ($ million)

	2001			2002			2003		
	Total Exports	Medical Devices	Share	Total Exports	Medical Devices	Share	Total Exports	Medical Devices	Share
United States	731,025.9	16,056.9	2.2%	691,862.6	16,274.2	2.4%	722,064.7	18,063.5	2.5%
Massachusetts	17,490.1	1,349.1	7.7%	16,564.1	1,324.1	8.0%	18,541.2	1,847.0	10.0%

Source: MISER 2004

Trends in Exports

Since 1998, the period for which trade data are available for comparison, medical-device exports from Massachusetts manufacturers to foreign countries have surged relative to overall merchandise exports from the state (see figure 8). While state merchandise exports grew by 18 percent between 1998 and 2003, medical-device exports grew by 78 percent. Most significantly for the state's economy, exports of medical devices were virtually unaffected by the recession. Medical devices are not subject to the same business cycle that affects the state's information-technology sectors. Although medical-device exports did not surge at the peak of the technology bubble as did overall exports (which were led by computers, electronics, and other IT-related products), neither did they decline in the recession.

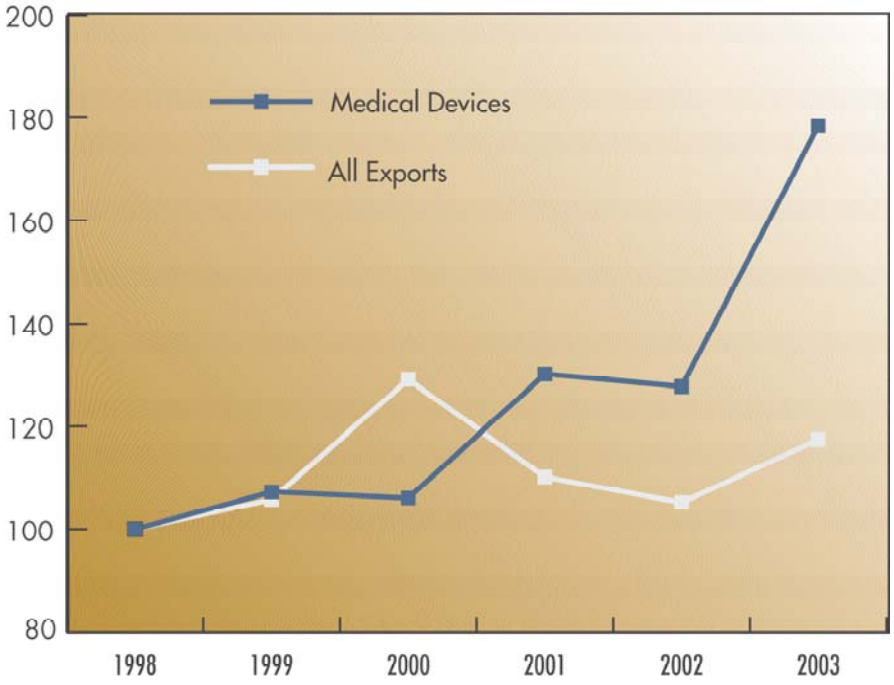
In fact, the cluster has been growing significantly over the past three years. Medical-device exports grew 36.9 percent between 2001 and 2003, an increase of close to $498 million. In contrast, total exports from Massachusetts increased only 6.0 percent during the same period of time. Table 3 shows this contrast.

Table 3. Massachusetts Exports: Medical-Device Industry vs All Industries, 2001–2003 ($ millions)

Exports	2001	2002	2003	Change 2001-2003 (%)
Medical Devices	1,349.1	1,324.1	1,847.0	36.9
All Industries	17,490.1	16,564.1	18,541.2	6.0

Source: MISER 2004

Figure 8. Massachusetts Merchandise Exports, Indexed (1998=100)



Source: MISER 2004

Partnering to Improve Patient Care in Massachusetts: Research, Clinical Trials, Skills Training, and Education

The development of medical devices in Massachusetts is characterized by strong collaboration between medical-device engineers in firms and practitioners at medical and research institutions. Various programs have been initiated by medical-device firms to nurture innovation, resulting in close relationships with the state's medical community. This collaboration promotes a climate of progressive care and creativity in the medical system, in turn leading generally to top-rate, cutting-edge care for patients. A look at some of the programs initiated by the Commonwealth's medical-device firms illustrates this process.

Equipment for blood donations and blood recycling developed by the Braintree-based firm **Haemonetics** is used by the major blood collectors in the United States as well as by medical-treatment centers across the world. The firm's blood-donation products automate the donation process to enable specific segments of the blood—for example, blood platelets—to be isolated, collected, and used. Clinical trials of Haemonetics equipment within Massachusetts insure that regional blood-collection protocols are both safe and efficient, and both end users and patients benefit from the automated process, as it simplifies the donation process and helps to ensure a fresh supply of blood for patients who need specific types of blood products.

Smith & Nephew Endoscopy, based in Andover, is the world's leading provider of devices for surgeons to repair joints, as well as new, minimally invasive—or endoscopic—techniques. Endoscopic techniques benefit patients by reducing physical trauma, complications, and overall healthcare costs. The company runs programs for Massachusetts surgeons, fellows, and residents in a variety of arthroscopic procedures like ACL repair, rotator-cuff repair, and hip repair. The company opens its facilities to practitioners from Massachusetts hospitals, providing lectures, opportunities for group discussions on surgical techniques, lab training on a variety of arthroscopic tools and techniques, and side-by-side learning with peers. The specialized training for

continued on page 13

Exports by Major and Minor Subsectors

To understand the range of exports within the industry, we look at both fine-grained industry-export activity and activity in the industry's major subsectors. We analyze nominal and percentage growth at both levels. Export data is presented using six-digit Harmonized System (HS) codes, an international method of classifying products for trading purposes. Six-digit industry codes related to the medical-device industry can be grouped into the following major subsectors:

- Diagnostic, Medical, and Surgical Instruments—including *electromedical apparatuses; syringes, needles, and catheters; medical and surgical instruments; mechanical and respiratory apparatuses; breathing appliances; orthopedic appliances;* and *x-ray apparatus and tubes;*
- Optical Instruments—including *polarizing material; contact lenses; spectacle lenses; frames and mountings;* and *sunglasses;*
- Medical Supplies—including *dressings; protective clothing; sterilizers;* and *wheelchairs.*

A look at major subsectors within the cluster shows that Diagnostic, Medical, and Surgical Instruments exports comprise 97.3 percent of 2003 exports from Massachusetts ($1.798 billion), making it by far the most significant of the major subsectors in terms of exports. At the same time, 1.8 percent of exports in the medical-device industry were Medical Supplies ($32.9 million), and 0.9 percent of such exports were Optical Instruments ($16.1 million).

Since 2001, exports of Diagnostic, Medical, and Surgical Instruments have increased steadily, whereas exports of Medical Supplies have increased at a slower rate. Optical Instruments exports have decreased by 34.0 percent (see figure 9).

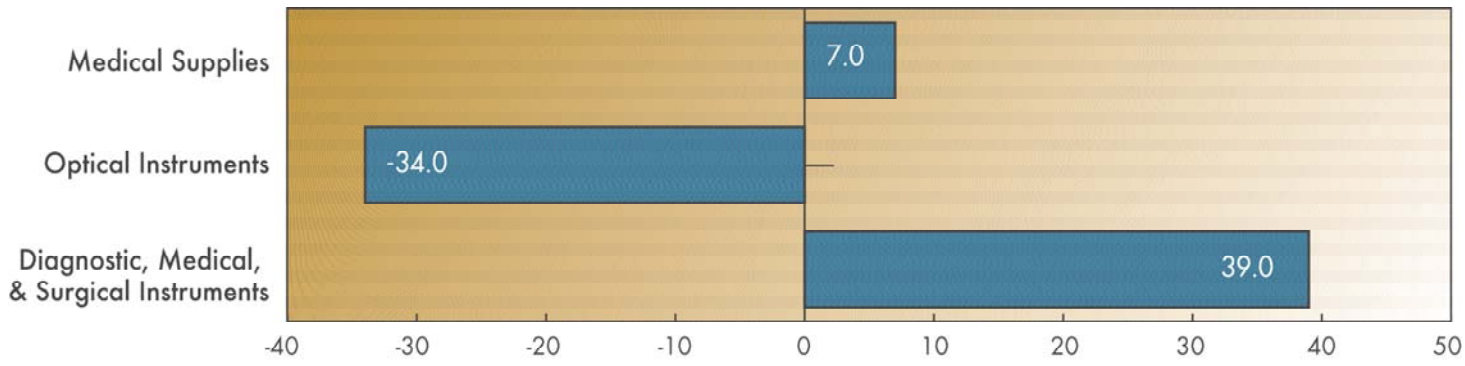
By far the most important increases in the entire cluster have come within the Diagnostic, Medical, and Surgical Instruments category. A full 46.9 percent of exports in this subsector are *syringes, needles, and catheters*. This represented a total of $842.6 million worth of exports in 2003. This product type has grown 57 percent since 2001, a vast increase compared to the national increase in this subsector of 20.3 percent. The second most important export category in this subsector is *medical and surgical instruments*, which make up 21.0 percent of the subsector, $377.2 million worth of exports in 2003. Massachusetts exports in this category have increased by 14.7 percent since 2001, more than twice as much as the 6.1 percent increase seen nationally in this same category.

Increases in exports in the Diagnostic, Medical, and Surgical Instruments category are shown in figure 10.

In 2002, three new Export Commodity Codes tracking orthopedic appliances, devices, and parts were introduced and included by the U.S. Census Bureau for the first time. Because they could not be tracked back to 2001, they are not included in the overall industry growth totals used in this analysis. However, these activities comprise a significant amount of export activity in the medical-device industry. In 2002 and 2003, respectively, the total value of Massachusetts exports in the new codes was $143.5 million and $121.4 million.

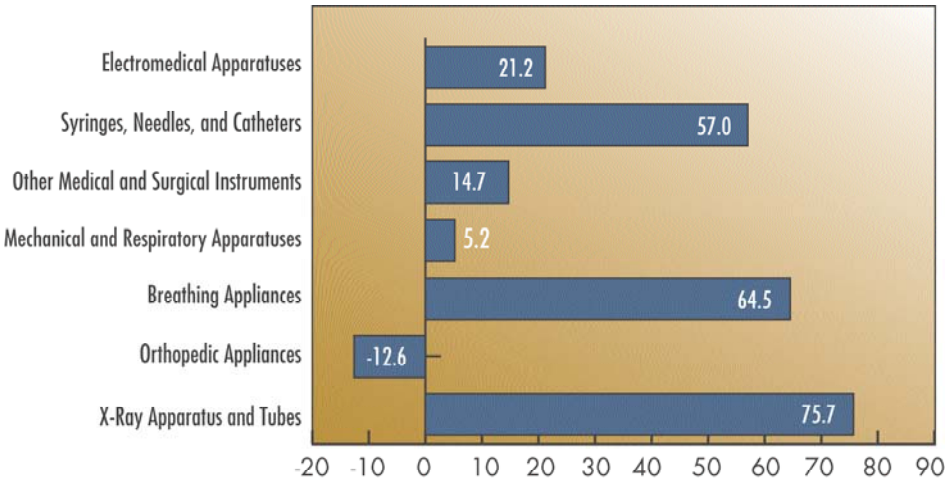
Electromedical apparatus exports were third highest of all subsectors in the industry, $355.2 million in 2003, growing 21.2 percent since 2001. The fourth-largest subsector in terms of exports is in the area of X-ray apparatus, with exports of $201.7 million in 2003, a growth rate of 75.7 percent since 2001. An outline of Massachusetts and U.S. export statistics regarding medical-device subsectors in the period 2001–2003 is given in table 4.

Figure 9. Medical-Device Subsector Exports from Massachusetts, 2001–2003 (Percent Change)



Source: MISER 2004

Figure 10. Diagnostic, Medical, and Surgical Instuments: Exports from Massachusetts by Product Type, 2001–2003 (Percent Change)



Source: MISER 2004

Table. 4 Medical-Device Exports by Product Type, Massachusetts and United States, 2001–2003 ($ million)

	2001	2002	2003	Mass. Percentage Change, 2001-03	U.S. Percentage Change, 2001-03
Medical Supplies	**30.7**	**30.9**	**32.9**	**7.0%**	**2.3%**
Dressings	26.4	24.4	27.5	4.1%	4.6%
Protective Clothing	0.8	0.9	0.8	4.6%	-36.1%
Sterilizers	3.4	5.5	4.4	29.6%	13.8%
Wheelchairs	0.1	0.1	0.1	13.7%	32.9%
Optical Instruments	**24.5**	**14.8**	**16.1**	**-34.0%**	**-5.6%**
Diagnostic, Medical & Surgical Instruments	**1,294.0**	**1,278.5**	**1,798.0**	**39.0%**	**26.9%**
Electromedical Apparatuses	293.1	269.6	355.2	21.2%	1.8%
Syringes, Needles, & Catheters	536.7	534.5	842.6	57.0%	20.3%
Medical and Surgical Instruments	328.8	297.6	377.2	14.7%	6.1%
Mechanical and Respiratory Apparatuses	10.5	8.6	11.0	5.2%	13.6%
Breathing Appliances	1.9	1.3	3.1	64.5%	22.1%
Orthopedic Appliances	8.2	7.1	7.2	-12.6%	62.2%
X-Ray Apparatus and Tubes	114.8	159.8	201.7	75.7%	14.6%
Total Medical-Device Industry	**1,349.1**	**1,324.2**	**1,847.0**	**36.9%**	**12.5%**

Source: MISER 2004

continued from page 11

Massachusetts surgeons results in a higher quality of care for Massachusetts patients.

Philips Medical Systems, based in Andover, has entered into numerous collaborations with Massachusetts companies and hospitals that aim to improve patient care and the delivery of health-care services. For example, Philips has redesigned and adapted its nuclear-medicine imaging equipment and entered into a joint venture with Theseus, a Cambridge-based start-up developing an imaging contrast agent for cancer therapy. In late-stage clinical trials, this new genomics-based combination of Philips imaging equipment and the contrast agent can show clinicians within hours rather than months whether or not chemotherapy or radiotherapy is working, enabling more rapid and personalized therapy for patients.

The company has also developed a number of productive relationships with academic medical centers and smaller hospitals in the Commonwealth. This ongoing collaboration continues to improve specialized medical care in the state. Some examples include a relationship with New England Medical Center to work to improve electrocardiography monitoring; a partnership with Beth Israel to fine-tune cardiac-imaging techniques; onsite trials at Caritas Holy Family Hospital in Methuen to test patient-monitoring systems and collect feedback; and tests of software products at UMass Medical System to improve medical practice in the medical system. Through the provision of improved methods and equipment, these collaborative programs directly benefit patients at the participating institutions and medical centers.

Additional involvement by Philips is aimed at improving public health in the Commonwealth. The company collaborates locally to distribute automatic external defibrillators in a variety of public places to improve the emergency response time for victims of cardiac arrest. The *Public Access Defibrillation Program* in New Bedford is an example of one such program. Other communities and areas of Massachusetts —Bourne, Nantucket, and Martha's Vineyard —also benefit from the presence of these devices in public places.

These and many other programs initiated by Massachusetts medical-device firms continue to create a better care environment for Massachusetts's patients and residents.

Table 5. Massachusetts Medical-Device Exports: Top Destination Regions
($ million)

	2001	2002	2003	Share 2003	Percentage Change, 2001–2003
Western Europe	740.1	725.9	1,043.2	57.9%	41.0%
Asia	406.8	388.7	508.1	28.2%	24.9%
Canada	79.6	91.0	116.8	6.5%	46.7%
Australia	33.3	40.4	47.6	2.6%	42.9%
Middle-Eastern Countries	15.6	15.9	37.3	2.1%	139.7%
South America	23.3	20.6	35.9	2.0%	54.5%
Africa	6.6	9.3	11.8	0.7%	78.5%
Total	**1,305.1**	**1,291.8**	**1,800.7**	**100.0%**	**38.0%**

Source: MISER 2004

Top Export Destinations

Export destinations for medical devices from Massachusetts are analyzed by regions of the world and by countries within these regions. The top destination region, by share of total 2003 medical-device exports, was Western Europe, which imported 57.9 percent of the medical devices exported from Massachusetts. Top destinations in this respect were the Netherlands, Germany, United Kingdom, France, and Belgium.

Asia was the second-largest importer, receiving 28.2 percent of the medical devices exported from Massachusetts. The largest importers of such goods in this region were Japan, China, Singapore, Hong Kong, The Republic of Korea, Taiwan, and India.

Canada was the third-largest importer region, as the recipient of 6.5 percent of medical-device exports.

Although not as large in terms of total share, medical-device exports from Massachusetts to other regions of the world also show significant growth between 2001 and 2003. The largest percentage growth in these exports was to the Middle East and to Africa—139.7 percent and 78.5 percent, respectively. Within the Middle Eastern region, the top importers were Saudi Arabia (increased 314.8 percent in that period), and Israel (increased 97.7 percent in that period). Table 5 shows both the top destination regions for Massachusetts medical devices in 2001–2003 and the percentage change in exports over that period.

VENTURE CAPITAL

By financing the development of new technologies in start-up firms, venture capital plays a crucial role in the growth of the medical-device industry. Massachusetts medical-device firms received a total of $141.3 million in venture-capital financing in 2003,[10] about half as much as they received in 2001, the year discussed in the last industry study (Clayton-Matthews 2001).

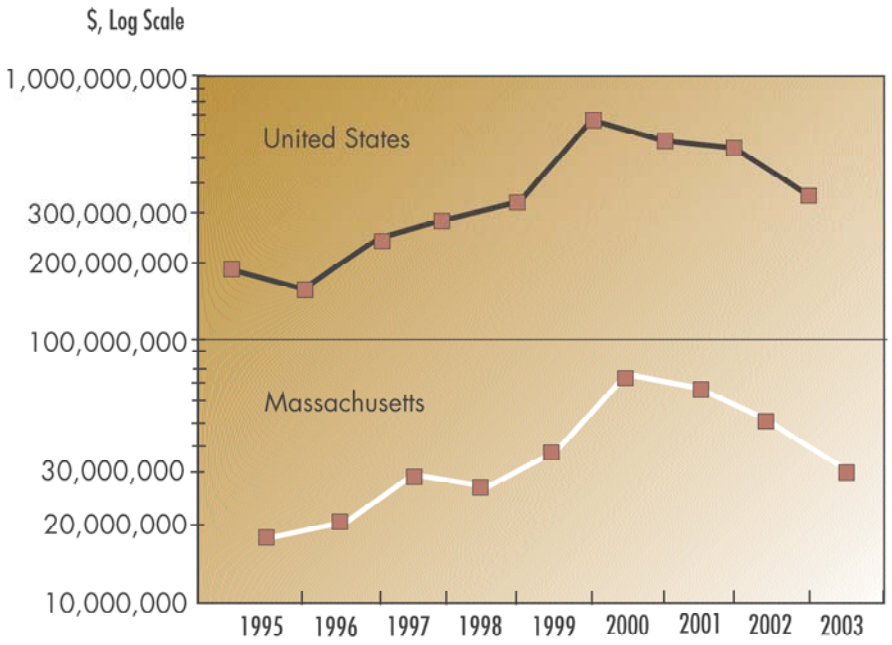
This fall in venture-capital funding from 2001 reflects the downside of the remarkable bubble in all venture-capital funding that burst in 2000. The swings in venture-capital funding in medical devices have actually been much less severe than for the whole VC market. While U.S. medical-device venture funding fell 48.6 percent between 2000 and 2003, total venture-capital funding fell by 85.5 percent over the same period of time.

The medical-device industry has shifted in industry rank since 2001. At that time, venture-capital investments in the medical-device sector were inferior only to information-technology (IT) and biotechnology sectors in respect to volume of venture-capital financing. In contrast, in 2003 the medical-device sector competes with the other four technology-related sectors for venture-capital funding: software, biotechnology, telecommunications, and networking and equipment. The total supply of venture-capital funding depends in part on investors' perceptions of the likelihood of successful "liquidity events" such as initial public offerings (IPOs) or acquisitions in which investors recoup their initial outlay plus a substantial profit.

Nationally, the medical-device industry received 8.6 percent of all venture-capital funding in 2003. The share of all venture-capital funds going to medical-device companies is roughly equivalent to that received by networking and equipment firms, but below that received by software, biotechnology, and telecommunications firms, as shown in figure 12.

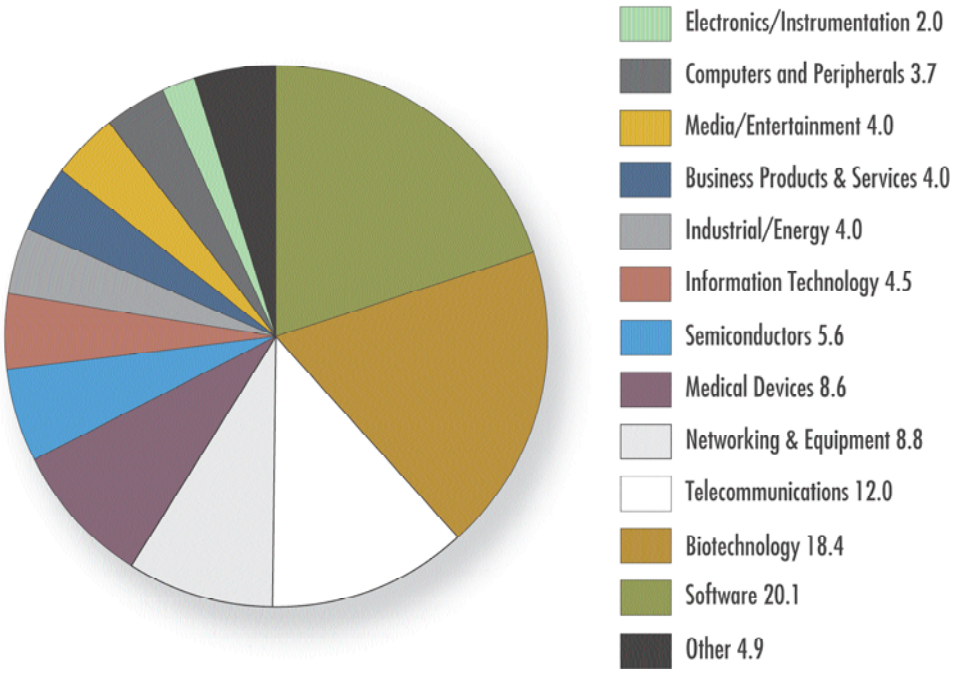
The relative unattractiveness of medical-device companies compared to IT ventures is largely due to the longer time of a liquidity event, especially an IPO outcome, because

Figure 11. Venture-Capital Investments in Medical Devices, U.S. and Massachusetts: Average Quarterly Investments



Source: PricewaterhouseCoopers 2004

Figure 12. U.S. Venture-Capital Funds, 2003 (Percent)



Source: PricewaterhouseCoopers 2004

of the time-consuming processes before profitable marketing: approval from the FDA to market, and approval from the Centers for Medicare and Medicaid Services (CMS) for consumer reimbursement after purchase. The time to profitability of IT ventures is perceived as much shorter.

The competition for venture-capital funds is also affected by the size of the expected return and the risk of a return. By their nature, venture-capital investments are risky. The expectation is that many, if not most, ventures will fail to be profitable, but that those that are profitable will be profitable enough to compensate for the failed ventures. Relative to biotechnology, medical devices are perceived to be less risky, but successes are perceived to be less profitable. The risk advantage derives from the small probability, in pharmaceuticals, of discovering a safe and effective drug relative to the probability, in medical devices, of developing a safe and effective instrument. On the other hand, the payoff for a successful drug is enormous relative to the payoff for a successful device, because once the drug or device is approved for marketing, the marginal costs of producing a drug are typically very small relative to those of producing a medical device.

Between 1995 and 2003 Massachusetts received roughly 11.4 percent of the total supply of venture-capital funds for medical devices in the United States, although the amount varied markedly in the short run. In the first quarter of 2003, Massachusetts medical-device companies received nearly 22.2 percent of the U.S. total ($63 million). In the next two quarters, Massachusetts companies received 4.9 percent and 12.1 percent of the U.S. total, respectively ($20 million and $46 million).

In the amount of venture-capital funding it receives, how does Massachusetts fare relative to other areas? In terms of its share of national venture-capital financing, the state does well. Its share, roughly 11 percent in 2003, exceeds what would be expected based on medical-device

industry measures, such as the share of national shipments, value added, and employment, which is approximately 5.9 percent. On the other hand, venture-capital funding is concentrated in a handful of regions, including Silicon Valley, New England, LA/Orange County, Southeast, North Central, San Diego, New York Metro, and the Midwest. New England, with its share of 17 percent, ranks second among U.S. regions. Although Massachusetts falls far behind Silicon Valley in the share of funds it receives, it ranks first among New England states, receiving 63 percent of New England medical-device venture-capital funds for 2003. These shares are illustrated in figure 13.

PATENTS

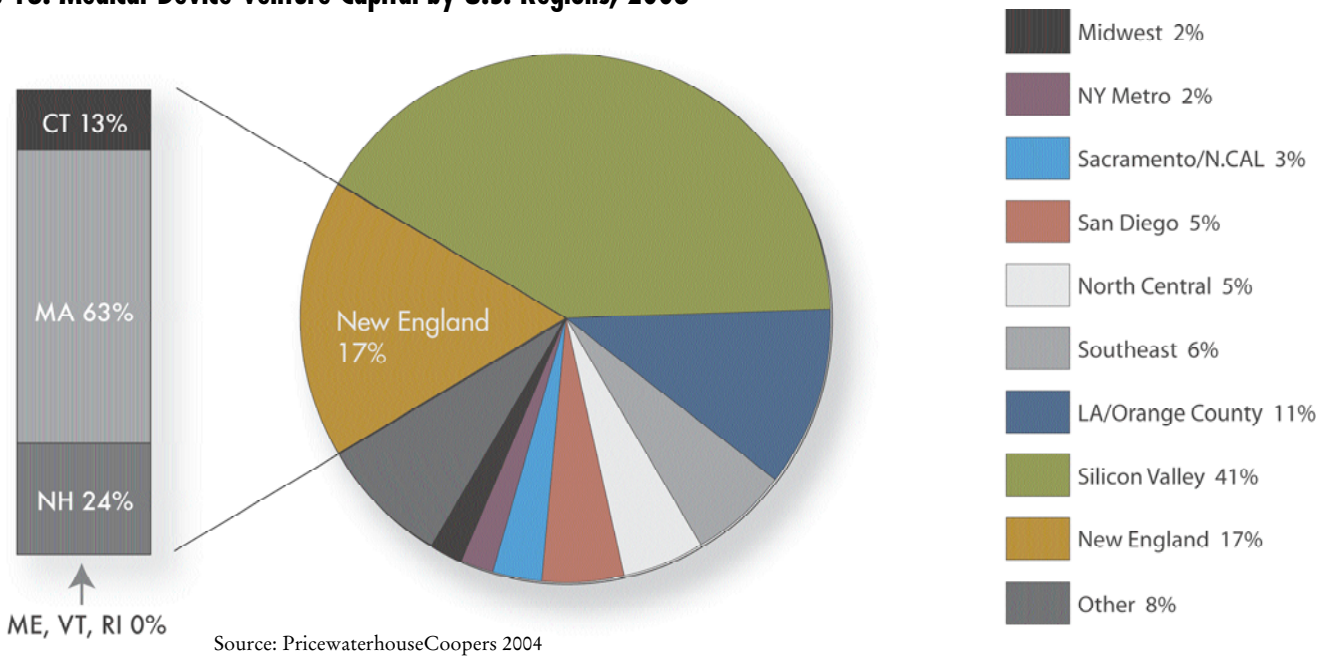
Competitor States: Medical-Device Industry

In order to analyze patents trends in Massachusetts, we took a comparative look at patents trends in five competitor states identified as such in the earlier study (Clayton-Matthews 2001). In that study, the top five medical-device states were identified in terms of both absolute size and per-capita measures of selected production characteristics, including value of shipments, employment, payroll, and value added. The 2001 study identified the top five competitor states as California, Minnesota, Massachusetts, Illinois, and Connecticut.

A look at industry trends between 2001 and 2003 shows that then, as now, California's medical-device industry is far larger than that in any other state. The distinctively large number of medical-device patents awarded to California since 2001—5,356 in all—reflects this difference in magnitude.

However, when it comes to medical-device patents awarded over time, Massachusetts continues to be a top competitor among U.S. states.[11] In terms of numbers of patents awarded, Massachusetts trails Minnesota slightly over the past three years—1,456 patents in Massachusetts versus 1,703 in Minnesota. However, the growth in patents awarded in Massachusetts was by far the highest growth rate of all five competitor states. Massachusetts-awarded patents grew 24.5 percent over the past three years. These differences are shown in percentages in figure 14 and in numbers of patents in table 6.

Figure 13. Medical-Device Venture Capital by U.S. Regions, 2003

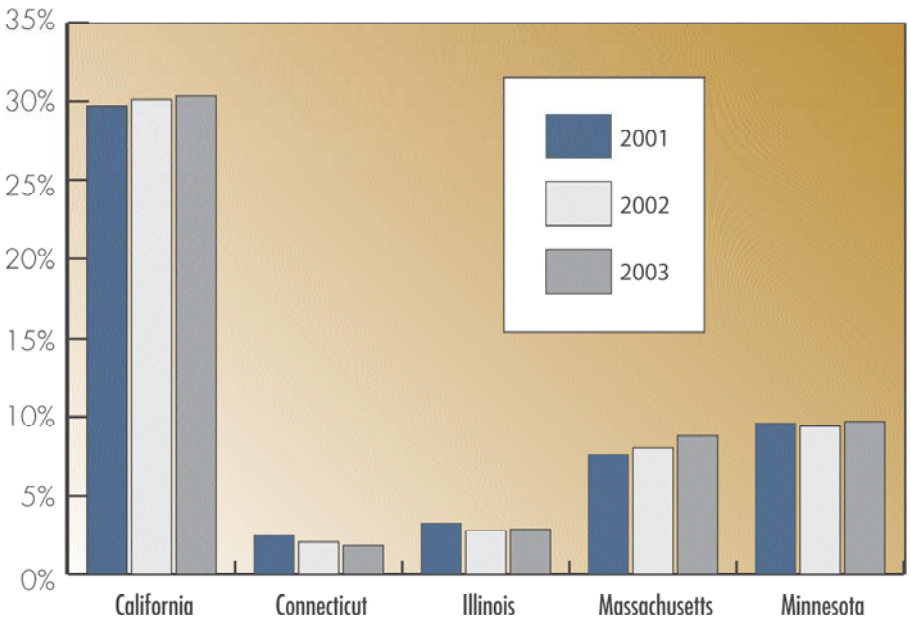


Source: PricewaterhouseCoopers 2004

Table 6. Number of Patents on Medical Devices				
	2001	2002	2003	Percentage Change 2001-2003
Total United States	5,875	5,587	6,366	8.4%
California	1,746	1,683	1,927	10.4%
Minnesota	564	523	616	9.2%
Massachusetts	449	448	559	24.5%
Illinois	193	157	187	-3.1%
Connecticut	144	116	119	-17.4%

Source: CHI Research Inc.

Figure 14. Share of Total U.S. Medical-Device Patents by State



Source: CHI Research Inc.

The growth in patents awarded in Massachusetts was by far the highest growth rate of all five competitor states.

Competitor-States' Patents by Technology Classification

Patents in the medical-device industry are granted in two technology classifications: *medical equipment*, which consists of nonelectronic medical and surgical devices and supplies, and *medical electronics,* which consists of diagnostic, imaging, and surgical equipment. The more significant of the two classifications as they relate to Massachusetts patents is *medical equipment*. Massachusetts was awarded 1,059 patents in this area between 2001 and 2003. In 2003, medical equipment–related patents comprised 8.5 percent of all patents awarded to Massachusetts. This proportion is higher than the proportion at the U.S. level, where *medical equipment* comprised 5.2 percent of all patents.

Among the top five competitor states in the medical-device industry, Massachusetts is very much like Minnesota in terms of patents awarded in medical equipment—the Massachusetts total trailed Minnesota's just slightly over the three years (1,059 versus 1,066 patents). Statistics for the top five competitor states and the United States are given in table 7.

In *medical electronics*, Massachusetts's performance is dwarfed by that of California in terms of the numbers of patents awarded. Massachusetts also ranks behind Minnesota in terms of awarded patents in *medical equipment*. In the period 2001–2003, Minnesota earned 637 such patents, whereas Massachusetts earned just 397. In 2003, *medical electronics* comprised 2.7 percent of all patents in Massachusetts, whereas such patents accounted for 1.8 percent of all patents at the national level. Medical-electronics patent data for the top five competitor states and the United States are shown in table 8.

Table 7. Medical Equipment Patents, 2001–2003			
	2001	2002	2003
United States	4,325	3,949	4,706
California	1,311	1,209	1,450
Massachusetts	317	318	424
Minnesota	354	310	402
Illinois	142	117	156
Connecticut	113	96	95

Source: CHI Research Inc.

Table 8. Medical Electronics Patents, 2001–2003			
	2001	2002	2003
United States	1,550	1,638	1,660
California	435	474	477
Massachusetts	132	130	135
Minnesota	210	213	214
Illinois	51	40	31
Connecticut	31	20	24

Source: CHI Research Inc.

Venture-Capital Investments versus Numbers of Patents, 2001–2003

Although Massachusetts and Minnesota are similar in terms of patents awarded in the medical-device industry in 2001–2003, Massachusetts received three times more venture-capital investments in medical-device firms in that period. This suggests that, despite the slightly lower number of patents awarded to Massachusetts over the three years, the commercial value of those patents may well be higher than those awarded to Minnesota. Private investors continue to see Massachusetts as a leading innovator in this area. This may explain the high volume of venture-capital investments in Massachusetts when compared to the other competitor states (aside from California). See table 9.

Science Linkage

Science-linkage coefficients are developed by CHI Research to indicate how leading edge are a company's technologies. Science linkage is defined as the average number of science papers referenced on the front pages of the company's patents. A high science-linkage coefficient indicates that a company is developing its technology based on advances in science. Companies at the forefront of a technology tend to have higher science linkage than their competitors. This type of referencing grows rapidly as companies become more technologically advanced. The average number of citations is roughly one per patent; drug and medicine patents often have five citations or more, and leading-edge biotechnology patents, fifteen citations (CHI Research Inc. 2004). Table 10 illustrates science-linkage scores of the top competitor states in the two spheres of the medical-device industry: medical equipment and medical electronics.

As we can see in table 10, in the period 2001–2003 Massachusetts is in the lead of both medical-electronics and medical-equipment areas in the United States. Taking into account the relatively small size of the Massachusetts medical-device industry compared to that of California, it is remarkable that Massachusetts represents the leading edge of medical-device companies' technologies, in terms of the depth of its science citations.

Table 9. Venture-Capital Investment in Medical Devices, 2001–2003		
State	Investments	Deals
California	2,748,670,000	292
Massachusetts	639,860,000	76
Minnesota	248,979,000	39
Connecticut	88,390,000	12
Illinois	28,400,000	3

Source: PricewaterhouseCoopers

Table 10. Science-Linkage Coeffients, 2001–2003		
State	Medical Equipment	Medical Electronics
California	4.40	3.67
Connecticut	2.12	4.17
Illinois	2.29	4.55
Massachusetts	5.17	6.39
Minnesota	4.41	3.00
United States	3.33	4.75

Source: CHI Research Inc.

CONCLUSIONS

■ The medical-device industry is an important and stabilizing influence on the Massachusetts economy:

- providing high paying manufacturing and management jobs;
- utilizing an extensive local supply base;
- leveraging intellectual capital from local research institutions and academic health centers in developing innovative medical products;
- attracting significant amounts of venture capital investment; and
- significantly contributing to total state exports.

■ While total jobs in the state's medical-device industry declined slightly from 1997 to 2002, annual shipments during this period increased by 25 percent, from approximately $4 billion to $5 billion, suggesting a high productivity rate for the sector's highly trained workforce.

■ The Massachusetts medical-device industry's widespread use of local suppliers also contributes to the state's employment base and total economic output. In addition, incomes generated in the medical-device industry impact the state's economy. Every hundred jobs in the medical-device sector is associated with another 79 jobs in related industries, which either supply medical-device firms or provide medical-device workers with goods and services. The sector is therefore responsible for creating 36,000 jobs in the Commonwealth. Furthermore, every dollar of medical device output in the state is linked to 45 cents of output from associated Massachusetts firms. In 2002, the total economic impact of the medical-device sector in the state equaled $7.3 billion.

■ Medical-device patents awarded to Massachusetts-based companies and researchers grew by 25 percent from 2001 to 2003—the highest rate of growth among leading medical-device states (California, Minnesota, Illinois, and Florida). This growth in device-related patents, and the high science-linkage coefficient of Massachusetts patents, coupled with the state's continued ability to successfully attract a sizable amount of venture capital suggest that the medical-device industry in Massachusetts is vibrant, growing, and leading-edge.

■ Massachusetts is home to some of the most important research institutions and academic health centers in the nation. To fully exploit the economic potential of the technology developed at these institutions, area medical-device companies should have the best access to the region's research base. The existing ongoing initiatives in integrating academic and engineering concerns should be encouraged and fully leveraged, including

- the Center for the Integration of Medicine and Innovative Technology (CIMIT);
- the Biomedical Engineering Alliance and Engineering Consortium (BEACON);
- the Bioengineering Institute (BEI) at Worcester Polytechnic Institute; and
- the Bio Economic Technology Alliance (BETA) of the Regional Technology Corporation in Western Massachusetts

In addition, the Commonwealth of Massachusetts has recently funded a statewide entity called the Massachusetts Technology Transfer Center (MTTC) whose mission is to facilitate the transfer of technology from public and private universities to Massachusetts companies. The MTTC will be managed by the University of Massachusetts and is scheduled to begin operations by the summer of 2004. The MTTC will focus on several emerging technologies that have been identified as critical to the Commonwealth's economic future including medical devices.

■ The presence of a significant medical-device sector in Massachusetts benefits the state's patients and health-care providers. Through industry-sponsored research, clinical trials, education, and skills training, the local health-care delivery system is greatly enhanced. As numerous Massachusetts companies partner with area academic health centers, patients and providers receive access to the latest and most innovative medical technologies.

The state's medical-device community is an integral component of the Massachusetts economy, providing high-paying jobs and designing and manufacturing some of the most innovative medical products available in the world. While not the largest technology-based cluster in the state, the medical-device sector has performed well despite downturns in the national and regional economies, making it an important part of the Commonwealth's economic portfolio of industries. Public policy makers should take special note of this and develop and implement legislation and regulations that support the medical-device industry's continued growth and expansion in the state.

REFERENCES

CHI Research Inc. 2004. http://www.chiresearch.com/information/stdinfoprods/ reg_tl.php3.

Clayton-Matthews, Alan. 2001. *The medical device industry in Massachusetts: Executive summary*. Boston: University of Massachusetts, Donahue Institute.

MISER. 2004. MISER foreign trade database 2004. http://www.misertrade.org/.

PricewaterhouseCoopers. 2004. Thomson Venture Economics and the National Venture Capital Association MoneyTree™ Survey. http://www.pwcmoneytree.com/moneytree/index.jsp.

U.S. Census Bureau. 2000a. Decennial census of the population. http://www.census.gov/main/www/cen2000.html.

——2000b. Public-use microdata samples (PUMS). http://www.census.gov/main/www/cen2000.html.

——2001. *Final Schedule B obsolete to new classification changes effective January 1, 2002*. Washington, DC: Commodity Analysis Branch, Foreign Trade Division, December 18.

——2003. EPCD, County business patterns. http://www.census.gov/epcd/cbp/view/cbpview.html.

U.S. Department of Commerce. 2000. *1997 Economic census*. Washington, DC: U.S. Census Bureau, Economics and Statistics Administration.

——2002. *North American industry classification system—United States, 2002.* Washington, DC: National Technical Information Service.

NOTES

1 The North American Industry Classification System (NAICS) is a governmental industry-coding system used by the U.S. Census Bureau and the public. It was developed jointly by the United States, Canada, and Mexico to provide new comparability in statistics about business activity across North America (http://www.census.gov/epcd/www/naics.html).

2 The exact figure was $3,996 million.

3 See the citation for the County Business Patterns in the references. The QCEW is the Quarterly Census of Employment and Wages (QCEW) (also known as ES-202), U.S. Department of Labor, Bureau of Labor Statistics (http://www.bls.gov.cew).

4 The 1997 payroll of $989 million is from the 1997 Economic Census. The payroll of $1,242 million for 2002 is the County Business Pattern estimate for 2001 of $1,165 million times the growth from 2001 to 2002 in medical instrument payroll for Massachusetts (NAICS industry 3391) of 6.6 percent from the Quarterly Census of Employment and Wages (QCEW).

5 The figures from the REMI model in this section were reported in the prior medical-device report (Clayton-Matthews 2001). The citation for the REMI model is: Regional Economic Models Inc. (REMI), (2000). Policy Insight Model, Massachusetts region, Amherst, MA.

Some medical-device industry executives have told us that they export far more than half of their product to other parts of the nation and world, and that actual exports for many medium to large medical-device companies may comprise more like 90 percent of output. We suspect that the REMI model's export share is too low and out-of-date for the medical-device sector. The MISER data, for example, show that international exports have grown by nearly 80 percent since 1998.

6 For each measure, first place was assigned five points, second was assigned four points, and so on through one point for fifth place and zero points for sixth or higher place.

7 The percentages in this sentence are for the population 25 years of age and older. In the rest of this section, the percentages refer to the appropriate group of workers.

8 This result is based on a regression of earnings on age, sex, race and ethnicity, educational attainment, marital status, occupation, and a dummy variable that indicates if the worker was a Massachusetts worker or not.

9 Export data in this analysis are from the U.S. Census Bureau, Foreign Trade Division, State Exports by HS data series, as adjusted and released by the Massachusetts Institute for Social and Economic Research (MISER). The foreign-trade data series measures export activity from each state by export commodity code on a quarterly and annual basis. For this analysis we identified and selected export commodity codes pertaining to the medical-device industry.

10 The data on venture capital in this section are from PricewaterhouseCoopers 2004.

11 Data in this section are from CHI Research Inc. 2004. Original data is from the U.S. Patent Office, normalized by CHI Research to allow comparisons across research fields and time periods.

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