The Competitive Position of BioBusiness Technology Industries in Minnesota within the United States

A Report of Research and Analysis Conducted for the

BioBusiness Alliance of Minnesota

Dr. Kelvin W. Willoughby

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Table of Contents

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Executive Summary

This report summarizes the results of a comparative analysis of the biobusiness technology industry in Minnesota and ten other US states known to be active in various technological fields of biobusiness. The analysis – an analysis of the relative competitiveness of Minnesota and the other states, within a national context, over the five years for which the most recent data are available – was conducted using standardized data produced by the U.S. Census Bureau from its periodic economic censuses and from related surveys of non-employer establishments in the United States. The industry categories employed in the study were selected from standard categories defined as part of the North American Industrial Classification System (NAICS), developed and implemented during the mid-1990s by the governments of the United States, Canada and Mexico. The NAICS categories were used in this study as rough proxies for the fields of activity that make up what is labeled herein as the "biobusiness technology" industry.

The results of the study show that Minnesota (while overshadowed by California, and faced with serious competition from a number of other states) is indeed a nationally prominent player in the medical devices industry (part of the larger biobusiness technology sector). Minnesota is competitive in medical devices. The results also reveal, however, that the state's relative leadership position in medical devices may be eroding due to strong competition from elsewhere.

After reviewing medical devices, the study's exploration of a second field – emerging industries centered on research and development in the life sciences (including biotechnology and other bio-centered fields of research) – shows that Minnesota, while gradually increasing its level of business activity in this domain, is not a leading state. Furthermore, Minnesota's competitive position in the life sciences R&D industry (also part of the larger biobusiness technology sector) – modest though it is – appears to have been eroding during the five most recent years for which data are available. Minnesota cannot afford, so it appears, to rely upon its

prowess in its emerging life sciences R&D industry to automatically compensate for its declining (although still quite competitive) position in the medical devices industry.

The whole biobusiness technology industry sector – including medical devices, R&D in the life sciences, pharmaceuticals, agri-bio technology, bio-industrial technology and other bio-related fields of technology – was also examined, in the third part of the study, using data produced by the U.S. Census Bureau, from 1997 to 2002. The analysis revealed that Minnesota's competitive position in the whole biobusiness technology industry, which was quite substantial in 2002 (approaching $7 billion annually in revenue within the state), was slightly above "average" for the United States. In other words, Minnesota is doing slightly better than might be expected for a state with an economy of its size. Against this good news, the study also revealed that Minnesota's national competitive position in the biobusiness technology industry appeared to be slipping during recent years (following 1997), despite an overall growth in the absolute numbers of jobs, enterprises and dollars generated by the industry. In short, despite its very real strengths (estimated for 2005 at more than 35,000 biobusiness technology jobs spread over about 950 biobusiness technology enterprises), Minnesota's competitive position appears to be eroding under the pressure of serious biobusiness technology efforts from other states.

The report concludes by arguing that Minnesota cannot afford to rest on its laurels from past successes in the medical devices industry. If Minnesota wishes to thrive economically in the vital new complex and interdisciplinary world of technological enterprise in biobusiness, it will need to take radical action, quickly. Minnesota's leaders in biobusiness will need to develop and implement new sophisticated strategies, with agility, prowess and speed, to maintain current strengths in the biobusiness technology sector, and to arrest the current erosion of the state's economic competitiveness in this exciting web of technological fields.

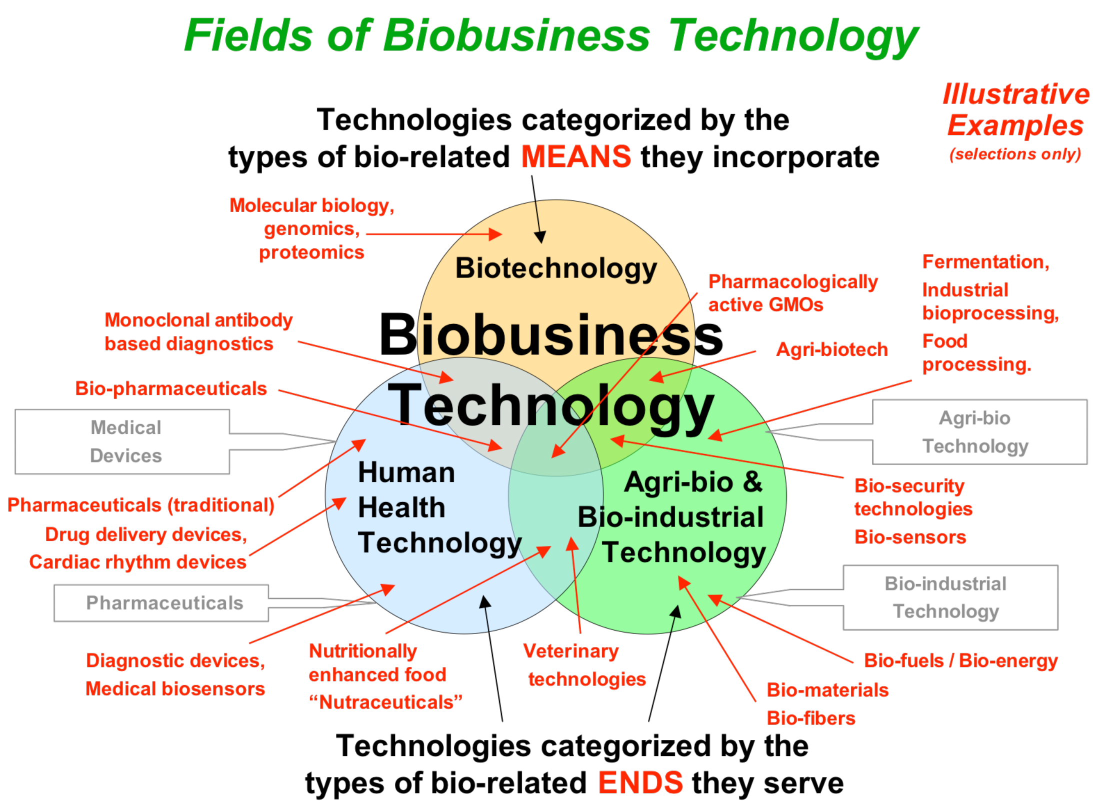
Such a sophisticated strategy would involve identifying, though a ground-up and rigorous technological mapping exercise, several fields of biobusiness technology where Minnesota could be the best in the world, or at least among the handful of the very best in the world. Policies and actions for nurturing the state's capabilities and performance in those several fields would need to be determined only after identifying the peculiar problems and needs of those particular fields. In short, Minnesota needs to find a way to stand apart in the biobusiness technology crowd rather than to follow standard strategies aimed at running along behind the ostensible current leaders in the crowd.

Introduction: Biobusiness Technology in Minnesota

Like many states and sub-regions within the United States, Minnesota is seeking to position itself as a major player in the broader domain of technology-based industries that are connected, in one way or another, with the world of biology. An enterprise devoted to this set of endeavors may be called a "biobusiness technology" enterprise.

We may say, simply, that **a biobusiness technology enterprise is a technology-based business focused on biology**. It may approach the biological domain as either a system of tools or as a field of application for technology. More particularly, a biobusiness technology enterprise may be defined as a biotechnology enterprise, a human health technology enterprise, a dedicated agricultural-bio or industrial-bio technology enterprise, or a combination of any of these types of enterprises. A biobusiness technology enterprise must be devoted to the goal of developing and/or commercializing bioscience or bioscience-related technologies, products or services. It does not necessarily need to have a successful end product on the market, but to qualify as a *bona fide* biobusiness technology enterprise an organization's activities must be directed towards the development of biobusiness technology. A biotechnology research laboratory in a university would qualify by this criterion as much as would a free-standing biotechnology firm. The general concept of biobusiness technology, which provides an organizing framework for the biobusiness technology industry sector, is illustrated in Figure 1.

Figure 1



Source: Dr. Kelvin W. Willoughby, 1996, 2005.

The primary data source for the analysis conducted in this study is the periodic **Economic Census** conducted by the **U.S. Bureau of the Census** together with data from the various **surveys of non-employers** associated with the Economic Census. The Economic Census profiles American business every 5 years, from the national to the local level. The Economic Census is based on a new standard industrial classification system (the North American Industrial Classification System – "NAICS"), developed and implemented by the U.S. Government during the mid-1990s, in cooperation with both Canada and Mexico. NAICS makes application of the U.S. Economic Census data useful for potential comparisons across the whole of North America. The new NAICS categories are also more suitable for mapping new science-and-technology based industries than were the old categories (based on SIC codes).

Despite these much welcomed advances, the industry categories employed by the U.S. Census Bureau in its five-yearly economic censuses (formalized as the NAICS codes) do not fit neatly with the concept of biobusiness technology industry. The NAICS codes tend, on the whole, to be based on product or market concepts; whereas the concept of the biobusiness technology industry (or industries) is based primarily on underlying technology concepts rather than product or market concepts (although, there are some product and market concepts built in to the concept of the biobusiness technology enterprise). As a consequence, it is impossible to find a set of NAICS codes that corresponds exactly to the wider boundary of the group of industries corresponding to biobusiness technology, as portrayed in Figure 1.

Nevertheless, with careful attention, it is possible to select a group of NAICS codes that may act as a proxy – or a rough and ready approximation – for the set of enterprises that make up the domain of biobusiness technology. After extensive study of the North American Industrial Classification System, this author selected the following NAICS categories (with their respective NAICS codes) as the best possible proxy set for the biobusiness technology industry sector:

3391: Medical equipment and supplies manufacturing
334510: Electromedical and electrotherapeutic apparatus manufacturing
334517: Irradiation apparatus manufacturing
3254: Pharmaceutical and medicine manufacturing
5417102: Research & development in the life sciences
6215: Medical and diagnostic laboratories
325193: Ethyl alcohol manufacturing
325221: Cellulose organic fiber manufacturing
311221: Wet corn milling
311222: Soybean processing
311223: Other oilseed processing
31212: Breweries
31213: Wineries

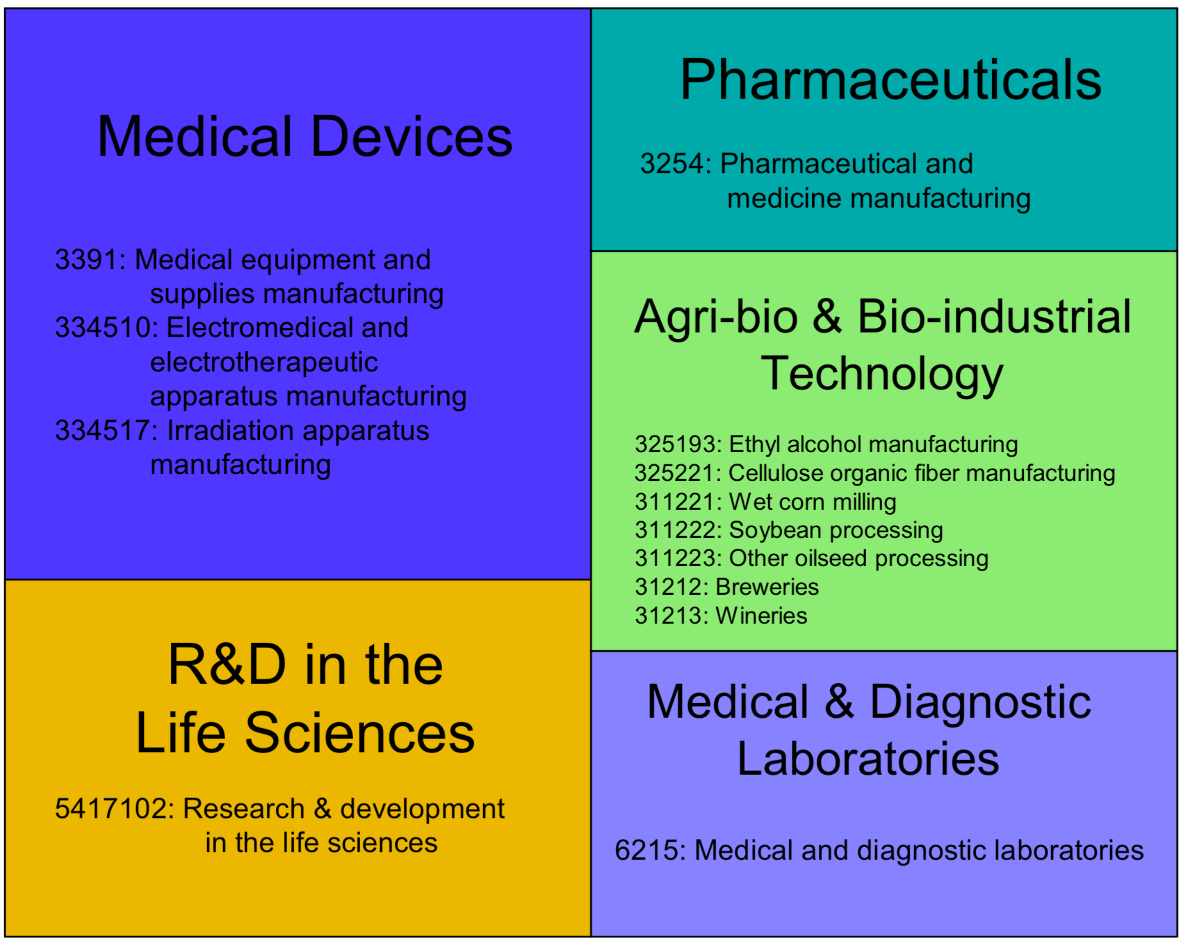
Further details, including a listing of the NAICS categories that have been used in this study as proxies for sub-categories of biobusiness technology – "medical devices" and "life sciences R&D" industries, for example – are provided in Appendix 1 of this document. Appendix 1 also provides additional NAICS codes that may be used as proxies to broaden the scope of analysis beyond biobusiness technology to the wider (although not comprehensive) domain of "biobusiness." Some commentators choose (inappropriately, it may be argued) to call this whole sector simply the "life sciences."

In an effort to fit in with the assumptions and concepts embedded in the NAICS categories, biobusiness technology in this study has been subdivided in to five sub-categories: medical devices, pharmaceuticals, R&D in the life sciences, agri-bio & bio-industrial technology, and medical & diagnostic laboratories. Figure 2 illustrates how the different NAICS-based sub-categories fit together under the general rubric of biobusiness technology. Biobusiness technology, in turn, is a sub-category of the even wider industry category of biobusiness (see Figure 3), that includes other less technology-intensive bio-related industries. This study focuses only on biobusiness technology and its sub-categories, and not on biobusiness as a whole. A proper treatment of biobusiness as a whole would require another study.

Figure 2

Biobusiness Technology Industries

(Map of NAICS-based categories)



The three combined categories of medical devices, pharmaceuticals, and medical & diagnostic laboratories illustrated in Figure 2 (themselves being aggregations of sub-collections of NAICS categories) are treated as a rough proxy for what is labeled as "human health technology" in Figure 1. The aggregated collection of NAICS categories labeled in Figure 2 as "agri-bio & bio-industrial technology" is treated as a rough proxy for the biobusiness technology category of the same name in Figure 1. The NAICS category in Figure 2 labeled as "R&D in the life sciences" is treated in this study as a rough proxy for the biobusiness technology category labeled in Figure 1 as "biotechnology." The NAICS category called "R&D in the life sciences" actually includes a broader array of biology-related fields of R&D than biotechnology (strictly defined), some of which perhaps really belong in what Figure 1 labels "agri-bio & bio-industrial technology." However, given the limitations of the NAICS data sets, treating "R&D in the life sciences" as roughly equivalent to what most people think of as "biotechnology" is a reasonable compromise to help us deal with the realities of publicly available data sets.

The "Research & development in the life sciences" category includes only R&D activities and not manufacturing activities. The official NAICS definition is: "Establishments primarily engaged in conducting research and experimental development in medicine, health, biology, botany, biotechnology, agriculture, fisheries, forests, pharmacy, and other life sciences including veterinary sciences."

The manufacturing components of biobusiness technology belong in a number of places. The medical devices category and the pharmaceuticals category are all manufacturing categories. In addition, the generic category labeled as "Agri-bio & bio-industrial technology" is a manufacturing category. Enterprises devoted primarily to R&D activities in agri-bio and bio-industrial technology are included within the "Research & development in the life sciences" category. Food technology companies come mostly under the broad category of "Agri-bio & bio-industrial technology." In the cases where food firms are devoted primarily to research and development activities, they are classified within the "R&D in the life sciences" category.

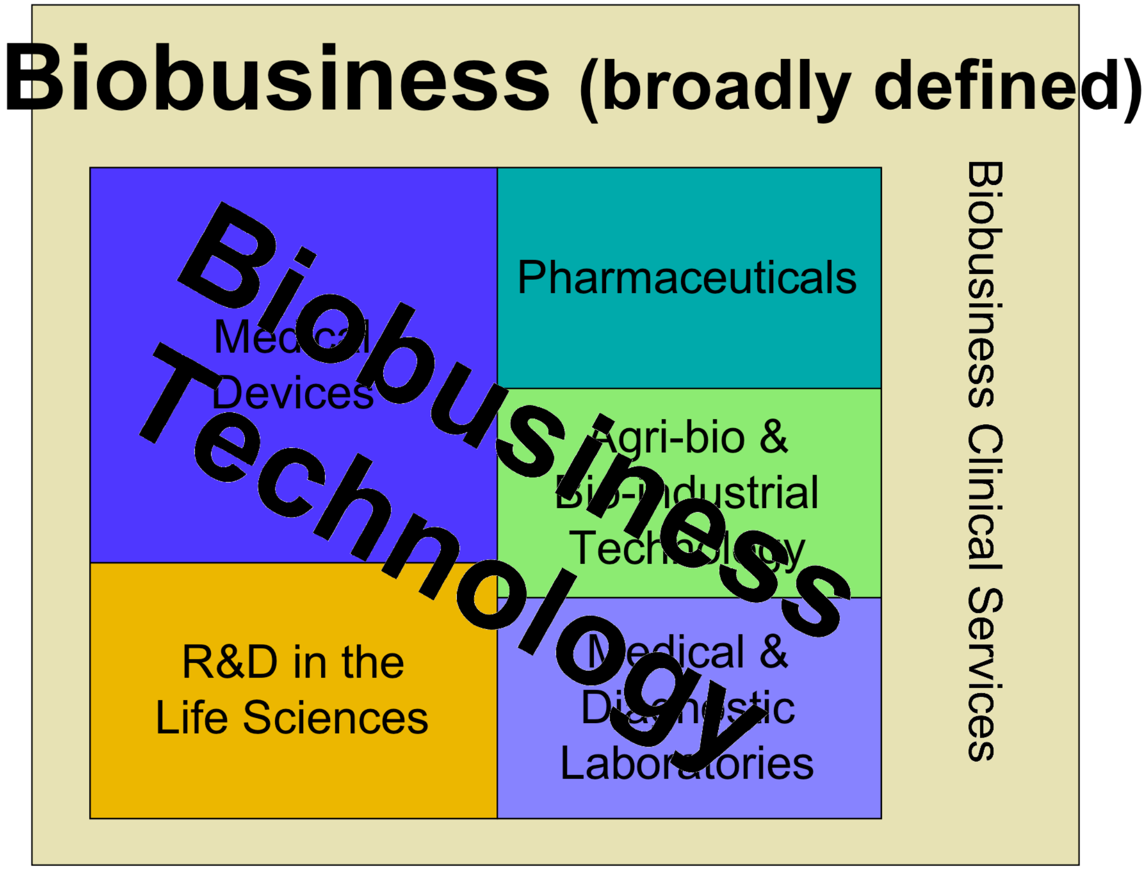
This competitiveness study included an early exploratory phase (Phase 1) designed to gain a preliminary sense of the feasibility of using NAICS categories as indicators of the status of biobusiness technology industries in Minnesota, in comparison with other U.S. states. Phase 1 was also designed to illustrate the difference in rationale between a standard "benchmarking" approach to industry analysis for Minnesota, using standardized national (typically high-level) data sources, and a "grass roots" approach (using a technology-centered framework for defining biobusiness technology) aimed at identifying truly distinctive areas of technological competence in Minnesota, especially in fields where multiple technologies converge.

NAICS categories are designed (intentionally, and for sound reasons) as discrete categories. Hence, the data in this study inevitably require each industry group to be treated as discrete; and the results of the study are based on the assumption that each of the enterprises in the population belongs in either one category or another (but not to more than one at the same time). The use of publicly available Economic Census data precludes counting a biobusiness technology enterprise as being more than one thing at the same time (e.g., being situated in the fields of medical devices and biotechnology simultaneously). The grass-roots approach, in contrast, has the advantage that not only can it employ more fine-tuned technological categories than is possible with NAICS codes, but it also enables more appropriate treatment of enterprises active in multiple fields. A grass roots study, however, requires more effort than would be feasible in the very short time frame allocated for this study.

An additional limitation of the Economic Census data is that they do not provide adequate coverage of the biobusiness technology activities of organizational units "hidden" inside universities, hospitals, government agencies, or other not-for profit organizations; nor do they properly reveal the non-incorporated biobusiness technology activities "hidden" inside corporations. A grass roots type of study is able to address this challenge, to reveal a more comprehensive picture of the reality of biobusiness technology in a community or region.

Figure 3

Biobusiness Technology & Biobusiness
(Map of NAICS-based categories)



Differences in the NAICS-based data sets used for the exploratory (Phase 1) part of this study and the main (Phase 2) part of this study are delineated in Appendix 2. A summary of the results of Phase 1 of this study is provided in Appendix 10 of this report.

A deeper explanation of the U.S. Economic Census and the sources of the data from the Census used in this study is provided in Appendix 3. Appendix 4 provides formal definitions of the set of NAICS categories that were chosen to act, in the aggregate, as a proxy set for the biobusiness technology industry.

This report continues, in the next section, with a brief summary of the status of the biobusiness technology industry in Minnesota, using the most recently available NAICS-based U.S. Economic Census data, complemented by estimates based on more recent NAICS-based data from the U.S. Department of Labor's Quarterly Census of Employment and Wages. It then focuses attention on the medical devices industry, a primary sub-category of the biobusiness technology industry. The report's treatment of the medical devices industry is followed by an analysis of the emerging industry centered on research and development in bioscience (very roughly equivalent to biotechnology, broadly defined). The report then returns to analysis of the whole biobusiness technology industry, as pictured in Figure 2 and as highlighted in Tables 1 to 5. The report ends by drawing general conclusions about Minnesota's competitiveness in biobusiness technology in the United States.

Highlights of Minnesota's Current BioBusiness Technology Industry Profile

With over 28,000 paid employees and annual revenues of almost $6.7 billion, distributed across more than over 900 enterprises (ranging from tiny one-person firms to large corporations) located within the state in 2002 (the most recent year for which comprehensive national data are available), **Minnesota's presence in the technology intensive industry sectors of biobusiness is substantial** (see Tables 1 & 2). Estimates and projections of recent developments in biobusiness technology in Minnesota since 2002, provided in Tables 3, 4 and 5, show that total employment levels are now probably greater than 35,000 spread across almost 950 enterprises.

Biobusiness Technology Industries in Minnesota

Table 1: Aggregate Figures, Minnesota, 2002

Biobusiness Technology Category	*Enterprises*	*Revenue ($1,000)*	*Annual payroll ($1,000)*	*Paid Employees*
Medical devices	439	$4,771,758	$1,077,962	21,966
Pharmaceuticals	58	$1,020,849	$100,084	1,928
R&D in the life sciences	121	$245,711	$97,658	1,752
Agri-bio & bio-industrial technology	25	$341,676	$14,512	1,056
Biobusiness technology (all industries)	**903**	**$6,613,261**	**$1,371,421**	**28,267**
Biobusiness clinical services	812	$9,061,865	$3,808,966	103,626
Biobusiness (broadly defined)	**1,715**	**$15,675,126**	**$5,180,387**	**131,893**

Table 2: Minnesota's Share of the US Total, 2002

Biobusiness Technology Category	*Enterprises*	*Revenue ($1,000)*	*Annual payroll ($1,000)*	*Paid Employees*
Medical devices	2.6%	5.8%	6.2%	5.5%
Pharmaceuticals	2.1%	0.7%	0.7%	0.8%
R&D in the life sciences	2.0%	0.9%	0.6%	0.7%
Agri-bio & bio-industrial technology	1.3%	0.7%	0.4%	1.4%
Biobusiness technology (all industries)	**1.6%**	**2.0%**	**2.2%**	**2.4%**
Biobusiness clinical services	1.8%	1.8%	1.9%	1.9%
Biobusiness (broadly defined)	**1.7%**	**1.8%**	**2.0%**	**2.0%**

Source: US Census Bureau, 2002 Economic Census (data); Dr. Kelvin W. Willoughby (calculations), 2006.

Biobusiness Technology Industries in Minnesota

Table 3: Estimates of Aggregate Figures, Minnesota, 2003

Biobusiness Technology Category	*Enterprises*	*Annual payroll ($1,000)*	*Paid Employees*
Medical devices	499	$1,582,300	24,389
Pharmaceuticals	65	$137,284	2,322
R&D in the life sciences	133	$105,396	1,891
Agri-bio & bio-industrial technology	32	$79,382	1,725
Biobusiness technology (all industries)	**917**	**$1,992,978**	**32,267**
Biobusiness (broadly defined)	*2,020*	*$6,337,631*	*143,745*

Table 4: Estimates of Aggregate Figures, Minnesota, 2004

Biobusiness Technology Category	*Enterprises*	*Annual payroll ($1,000)*	*Paid Employees*
Medical devices	501	$1,914,602	25,493
Pharmaceuticals	65	$163,272	2,502
R&D in the life sciences	128	$113,748	2,041
Agri-bio & bio-industrial technology	38	$80,423	1,760
Biobusiness technology (all industries)	**932**	**$2,376,703**	**33,851**
Biobusiness (broadly defined)	*2,051*	*$7,068,526*	*146,434*

Table 5: Estimates of Aggregate Figures, Minnesota, 2005

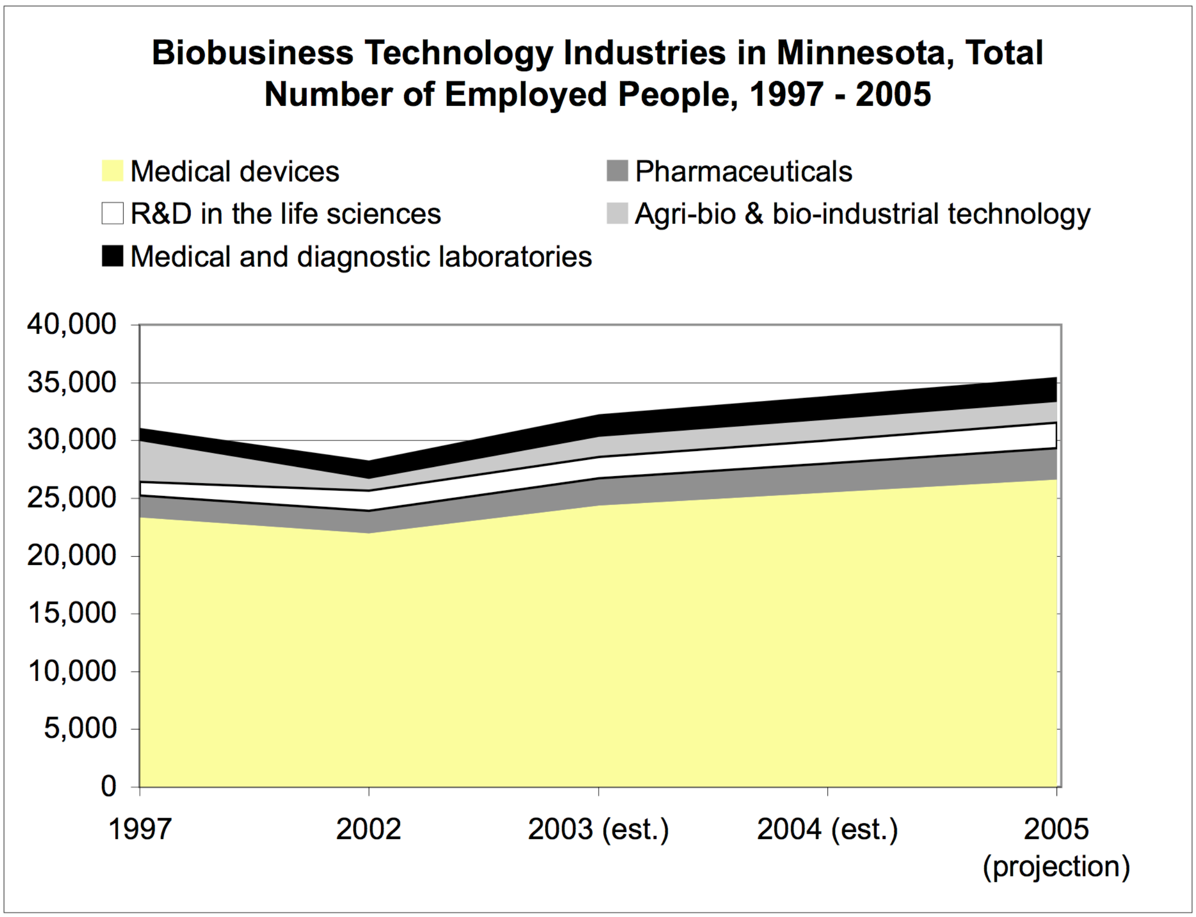
Biobusiness Technology Category	*Enterprises*	*Annual payroll ($1,000)*	*Paid Employees*
Medical devices	504	$2,316,691	26,647
Pharmaceuticals	65	$194,180	2,695
R&D in the life sciences	132	$122,761	2,202
Agri-bio & bio-industrial technology	45	$81,478	1,796
Biobusiness technology (all industries)	**947**	**$2,834,311**	**35,513**
Biobusiness (broadly defined)	*2,082*	*$7,882,933*	*149,174*

Source: All numbers in Table 3, Table 4 & Table 5 are estimates produced by Dr. Kelvin W. Willoughby based upon data drawn from the Quarterly Census of Employment and Wages, U.S. Dept. of Labor, Bureau of Labor Statistics, and the Labor Market Information Office of the Minnesota Department of Employment and Economic Development (March 2006), together with data from the 2002 Economic Census, US Census Bureau (March 2006). Numbers for 2005 are projections based on trends between 2003 and 2004. Raw data for 2005 were insufficient for producing reliable estimates in all fields.

The numbers in Tables 1 to 5 exclude biobusiness technology enterprises located inside universities, inside government agencies, and inside firms that are not classified by the U.S. Census Bureau as belonging to one of the industry categories included in this study as proxies for biobusiness technology industries. The actual economic value of biobusiness technology enterprises to the State of Minnesota is therefore probably significantly larger than appears here. Precise descriptions of the NAICS codes included in the data used to create these tables are provided in Appendices 1, 2 and 4 of this report. Minnesota's traditional strength in medical devices is reflected in the fact that the state's share of total U.S. employment in the medical devices sector (5.5%) is over twice that of its share of employment in biobusiness technology industries as a whole (see Table 2). The equivalent ratio for revenue is almost three-to-one.

Figure 4 takes the aggregate data on employment from Tables 1 to 5 and graphs these from 1997 to 2005. In addition to the overall increase in the level of employment in Minnesota's biobusiness technology sector over eight years, the graph also reveals how the medical devices sub-sector continues to be the dominant biobusiness domain in the state.

Figure 4



Minnesota's Competitive Position in the Medical Devices Industry

Given Minnesota's widely known historical strengths in the medical devices sector, it will be instructive to first of all examine the state's competitive position in medical devices, before looking at the broader array of biobusiness technology industries.

Figure 5

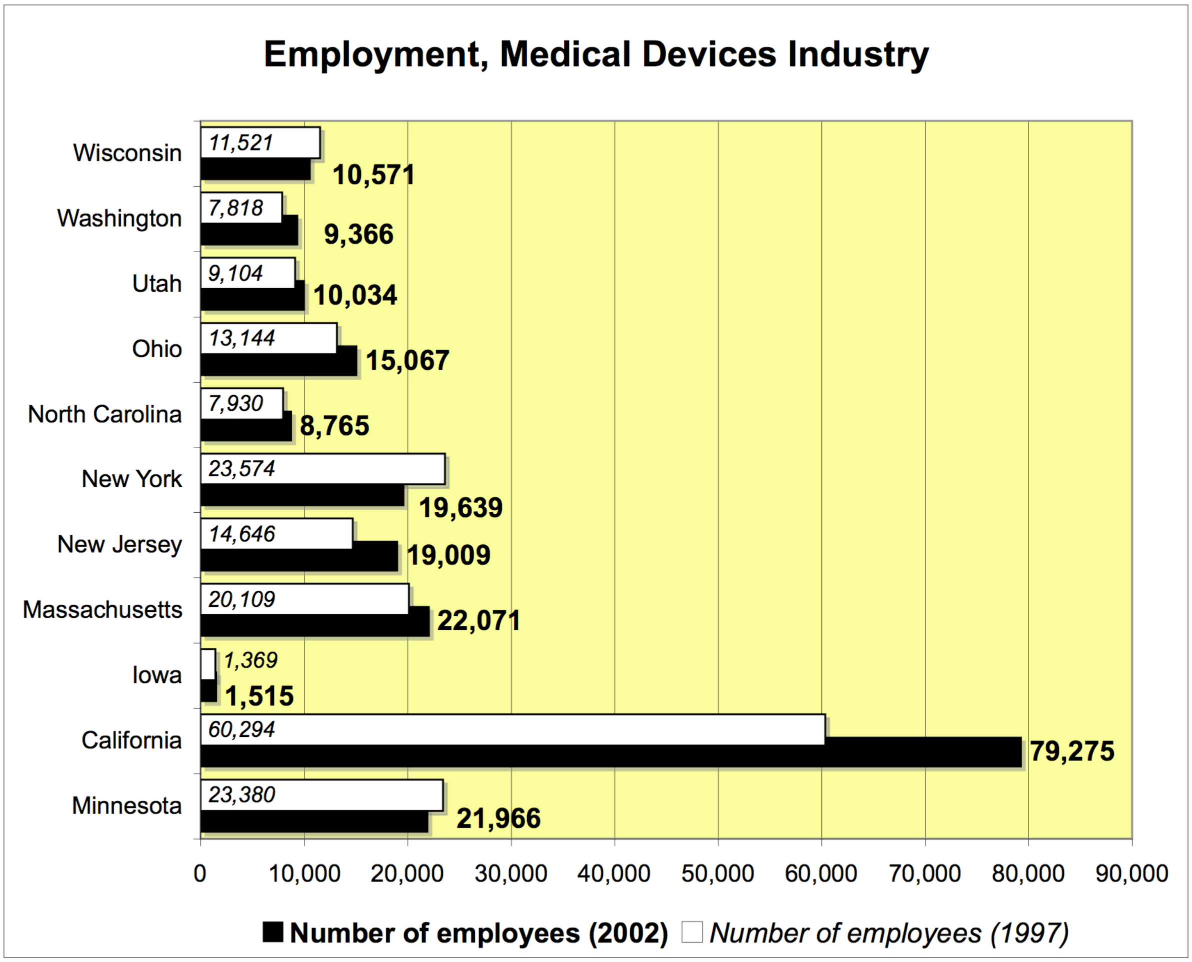


Figure 5 compares Minnesota with ten other U.S. states that are widely regarded as prominent players in biobusiness technology, which are of interest because of similarities or differences they exhibit vis-à-vis biobusiness in Minnesota, or which are often considered by policy analysts and industry observers to be peer states of Minnesota. The list of ten states is not meant to be exhaustive; it is intended to be indicative for competitive analysis. Figure 5 confirms the widely held belief that (of the group of U.S. states listed) **Minnesota is among the leading states**. It is surpassed in its total medical devices industry employment only by California (and comes in roughly equal second with Massachusetts). A particularly sobering fact revealed in Figure 5, however, is that in 2002 California has a medical devices industry about 360% larger than that of Minnesota, measured by total employment levels.

Figure 5 also shows medical devices industry employment in eleven states at two points in time, 1997 and 2002. During that five-year period, both California and Massachusetts expanded their total medical devices industry employment, whereas Minnesota actually contracted marginally. Both New York and New Jersey, furthermore, are now close competitors of Minnesota in medical devices employment, with New Jersey in particular having shown impressive growth over the previous five years. These numbers suggest that Minnesota's general leadership position as a medical devices employer may be eroding during recent years.

Figure 6

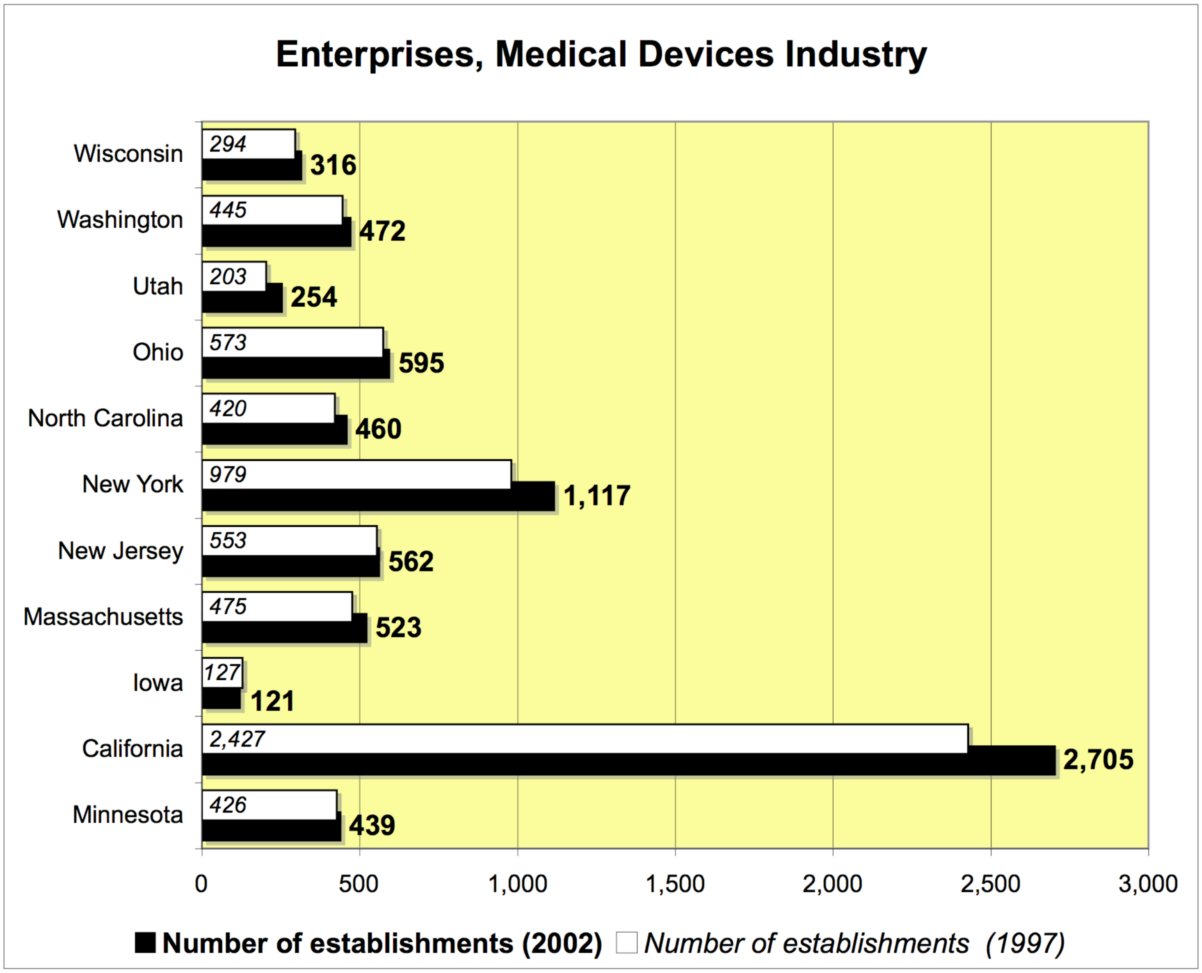
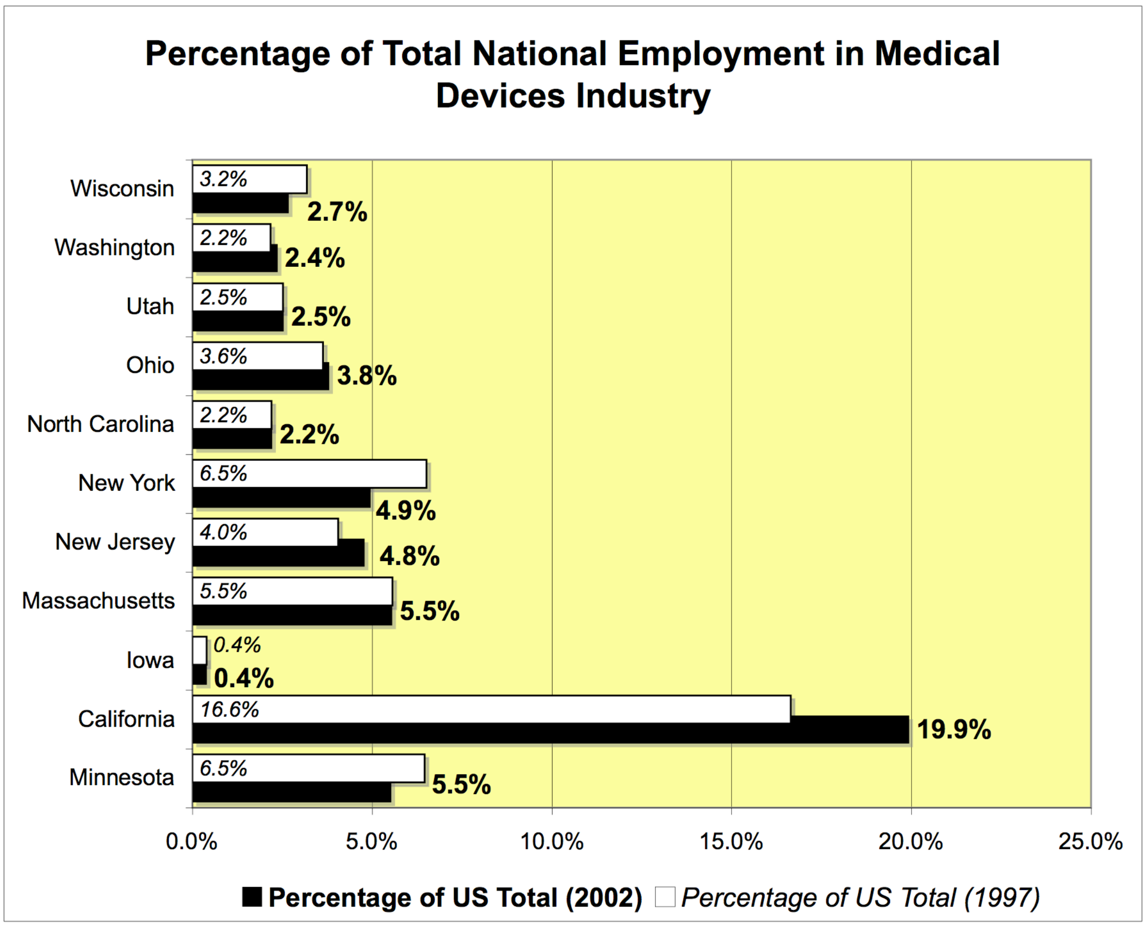


Figure 6 contains the same type of information as Figure 5, except that it compares the number of medical devices enterprises in each of the eleven selected states, rather than the total number of employed persons. **Minnesota increased its number of medical devices enterprises marginally over the five years to 2002**; but so did most of the other ten states. By the end of 2002 California was home to over 600% more medical devices enterprises than Minnesota. The fact that the ratio of California over Minnesota is significantly larger for enterprises than it is for employment suggests that California exhibits a more entrepreneurial structure to its medical devices sector than does Minnesota. The average size of Minnesota's medical devices firms (about 50 people per firm) is greater than that of California (about 29 people per firm).

Minnesota's medical devices enterprises typically appear to be more mature than those of California. The average size of enterprises in Massachusetts is roughly similar to that of Minnesota (suggesting that the maturity / entrepreneurship balance of those two states is similar).

Interestingly, while New York also lost some ground in total medical devices employment from 1997 to 2002, that state appears to have shifted slightly towards a more small-business or entrepreneurial structure for its industry. Like California, New York exhibits a more entrepreneurial structure to its industry than does Minnesota. The growth in the number of new enterprises in New York in recent years, combined with its relatively large existing base of medical devices enterprises, suggests that it may be a competitor for Minnesota to watch in the near future (despite New York's recent decline in the total number of medical devices jobs).

Figure 7



The fact that California has many more medical devices jobs than Minnesota, and that a number of other states now have more medical devices enterprises than Minnesota is not, in itself, a cause for concern. These states have much larger populations than Minnesota (California's population, in particular, is an order of magnitude larger than that of Minnesota) so, with all things being equal, we would expect those states to generate larger industries than Minnesota. Figure 7 was produced to try to put these factors in to perspective, by expressing each state's medical devices employment as a percentage of the U.S. national total, rather than as an absolute number.

California is home to about one fifth of all medical devices industry employment in America; Minnesota and Massachusetts come in equal second with a 5.5% share each. Another sobering fact is revealed in Figure 7: while Massachusetts has held steady at 5.5% of the national share, Minnesota actually dropped by one percent over the five year period from 1997 to 2002. California, on the other hand, despite its widely touted “inhospitable business climate” (due to high real estate prices and high wages), actually increased its national share by over three percent during the same period. **Is this rise in California’s prominence in the national medical device sector, both in relative share and absolute numbers, really an issue about which Minnesota ought to be concerned?** Before seeking to answer this question it is appropriate to conduct some deeper analysis, that takes in to account in a systematic manner the relative size of the whole economy in each state, and that weights each state’s contribution accordingly.

One way to do this is through what may be labeled generically as an “industry density index.” An industry density index may be used as an indicator of the relative capacity of regions to generate a particular kind of industry. Each index tells you something about the regional strength of an industry, standardizing the figures to take into account differences in the scale of the economies in the regions (e.g., states) under consideration, the state of the industry in the larger region (e.g., nation, as the case may be), and the current state of the whole economy throughout the nation (or whatever reference region is used).

The indices take into account that, with all other things being equal, one would expect to find a large scale industry (of a specified kind) in a large community, and a corresponding small scale industry (of the same specified kind) in a small community. For example, you would expect to find more restaurants in Minneapolis-St. Paul than in Rochester, simply because of the larger population in the metropolitan area, but the fact that this was the case would not tell you if the restaurant industry was any more *dominant* or *strong* in the Twin Cities than in Rochester. Industry density indices enable "fair" comparisons between regions, standardizing for differences in the scale of the regional economies.

The industry density indices are designed so that they always compute to "1.0" for the reference region. A region with an industry density index of less than 1.0 is less productive than would be expected as "normal" for generating activity in that particular industry; whereas a region with a score of above 1.0 has above-average productivity in generating a local presence of the respective industry. Under certain assumptions, the indices may be used to suggest differences in the competitiveness of the regions under study.*

Industry density indices can be calculated for any industry, and may be based upon any standardized factor that is a reasonable indicator of the level of activity of a particular industry that occurs in multiple local regions within a larger reference region. Such standard factors may include employment, number of firms, level of revenue, payroll levels, the financial capital base of enterprises, or the size of intellectual property assets, among other things. A key requirement for calculating these indices is that uniform, standardized, data have to be available across the local regions of interest. Employment is typically the most useful, and robust, industry factor to be included in the calculations for these indices.

The data assembled every five years by the U.S. Census Bureau, as part of its Economic Census, lend themselves extremely well to the calculation of industry density indices for industries located in the United States.

* In some academic disciplines the particular kind of industry density index labeled in this report as an "employment density index" is known as a "location quotient."

A generic formula for calculating an industry density index (IDI) for *industry X* in *region N*, using *factor F* as a source of data within a wider reference region (*region R*) is as follows:

$\text{Industry}_x\ \text{IDI}_f$ for region_n = {(factor$_f$ for industry$_x$ in region$_n$)/(factor$_f$ for industry$_x$ in region$_r$)}/{(factor$_f$ for all industries in region$_n$)/(factor$_f$ for all industries in region$_r$)}

For example, if industry$_x$ = "medical devices," if factor$_f$ = "employment," if region$_n$ = "Minnesota," and if region$_r$ = "USA," then the formula for calculating Minnesota's medical devices employment density index (EDI), within the nation as a whole, is as follows:

Medical devices EDI for MN = {(employment in the medical devices industry in Minnesota)/(employment in the medical devices industry in USA)}/{(employment in all industries in Minnesota)/(employment in all industries in USA)}

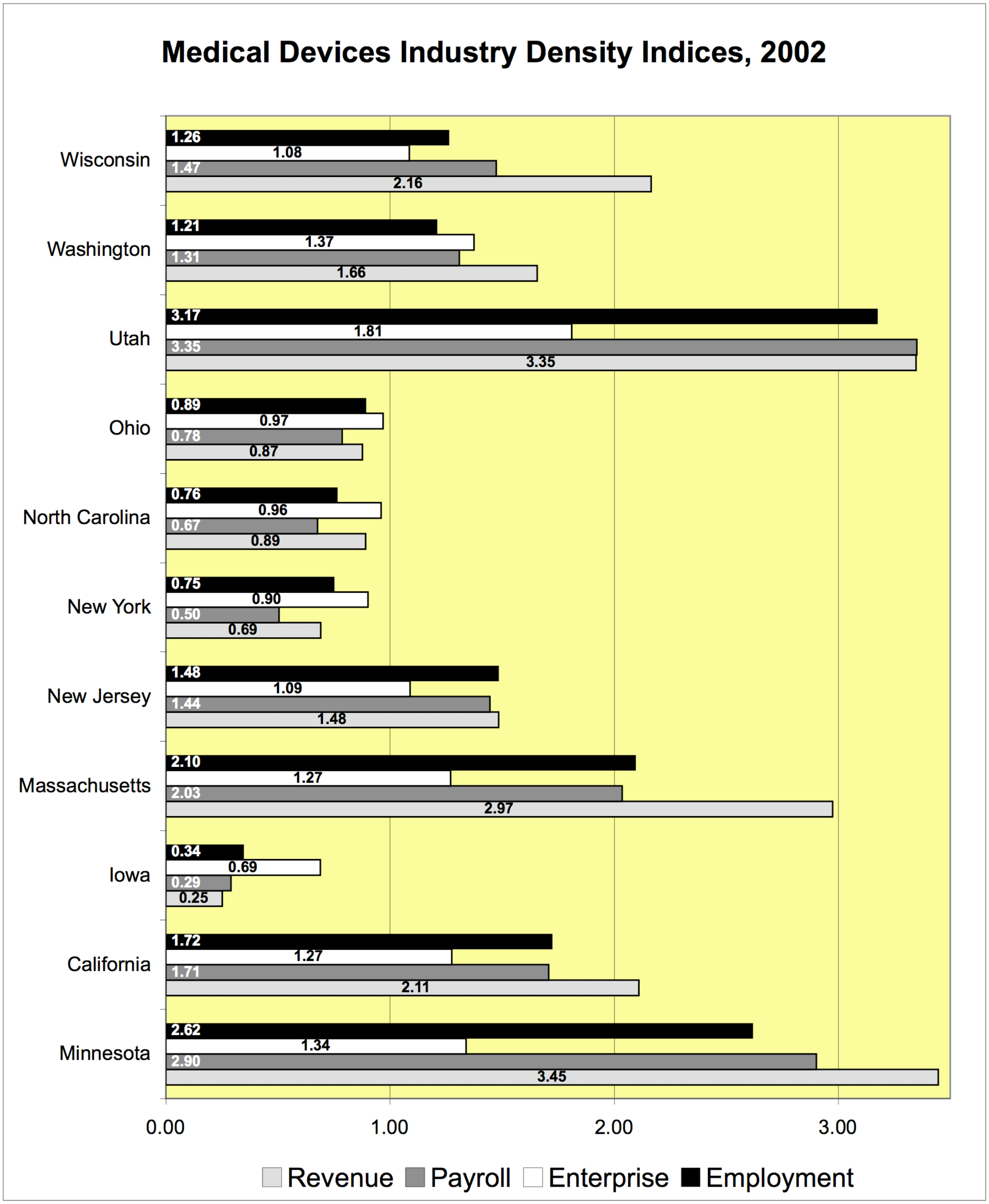
Figure 8 exhibits the results of applying the above formula to Minnesota and ten other regions (U.S. states) for the medical devices industry, using data for the following four industry factors drawn from the 2002 Economic Census conducted by the U.S. Census Bureau:

- Employment *(total number of paid employees)*
- Enterprise *(total number of establishments, with employees and without employees)*
- Payroll *(total annual payroll in enterprises)*
- Revenue *(total annual receipts – i.e., income – of enterprises)*

Figure 8 reveals that, when the relative size of their two economies is taken in to account, and when the size of the whole medical devices industry nation-wide is taken in to account, then **Minnesota is significantly more productive than California in generating medical devices industry employment** (i.e., it is more "efficient" than California in generating medical devices employment – actually, in 2002 Minnesota was over one and a half times as efficient as California in this regard – given the overall economic resources at its disposal). Minnesota's relative efficiency over California in generating revenue for medical devices enterprises is even greater than its lead in the area of employment. The exception to this pattern, as also shown in Figure 8, lies in the area of new enterprise creation (i.e., entrepreneurship in medical devices). California and Minnesota both appear to be roughly similar in this area, with enterprise density indices in the vicinity of 1.3 (both exhibit above-average levels of medical devices industry competitiveness).

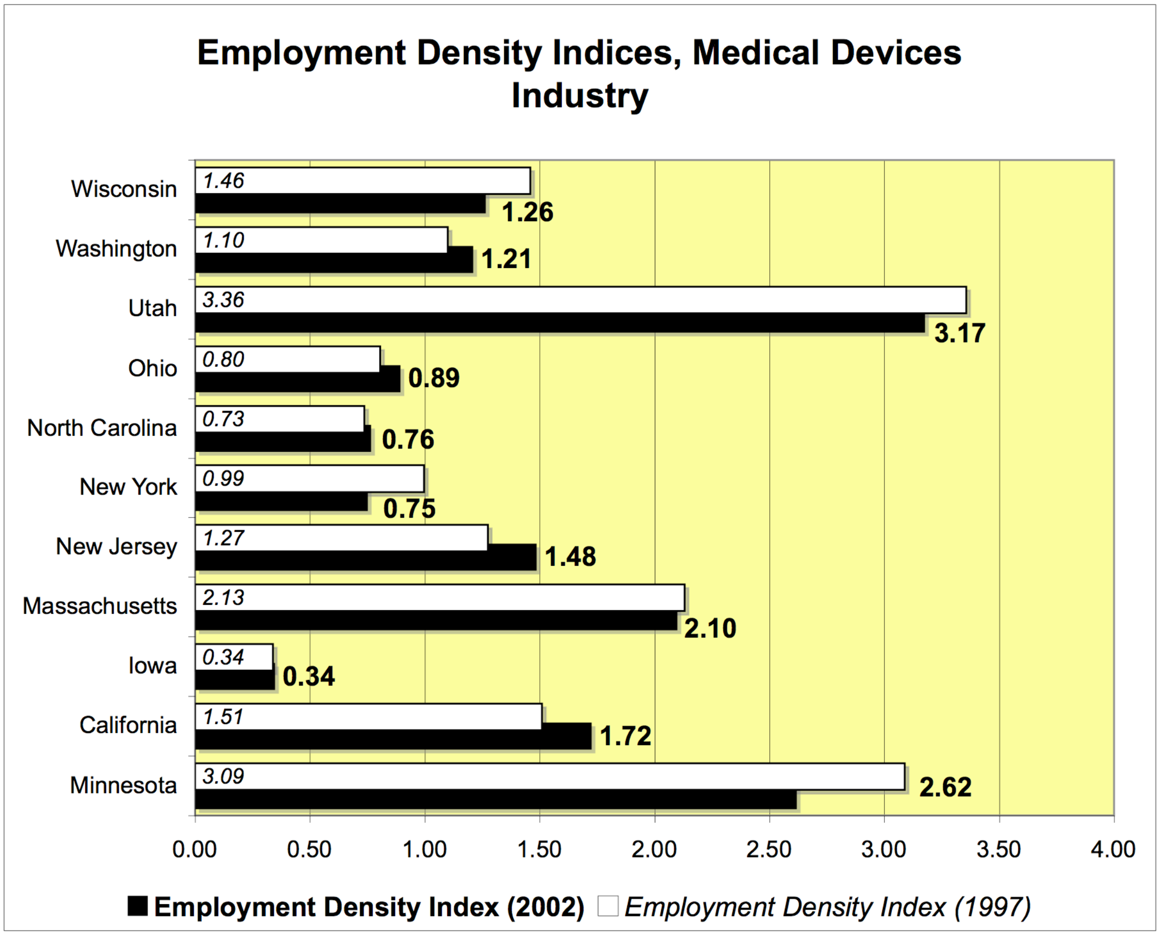
According to the calculations graphed in Figure 8, the following states are "competitive" in the medical devices industry (i.e., they have industry density indices greater than 1.0): Utah, Minnesota, Massachusetts, California, New Jersey, Washington, and Wisconsin. The following states, by the same logic, are less than competitive, overall, in the medical devices industry: Iowa, New York, North Carolina, and Ohio. Given the size of their respective economies, we would expect these four states to have done better. The good news for Minnesota is that it is strong (from the point of view of **industry density** in the medical devices sector). This accords with the general intuition of most informed commentators and observers of the medical devices industry. The troubling news, however, is that while Minnesota is definitely in the leading group, it is not unique. In fact, Utah (a much smaller state than Minnesota) does better, overall, than Minnesota in generating medical devices industry activities, given the size of its economy.

Figure 8



An even more powerful way to evaluate the competitive position of a state, in a particular industry, is to examine changes in its industry density indices over time, compared with other states. Figure 9 does this for employment density indices for eleven states for the five years between 1997 and 2002. Of the eleven states compared, Minnesota is the second most competitive (i.e., efficient at generating jobs) in the medical devices sector (behind Utah) for both 1997 and 2002.

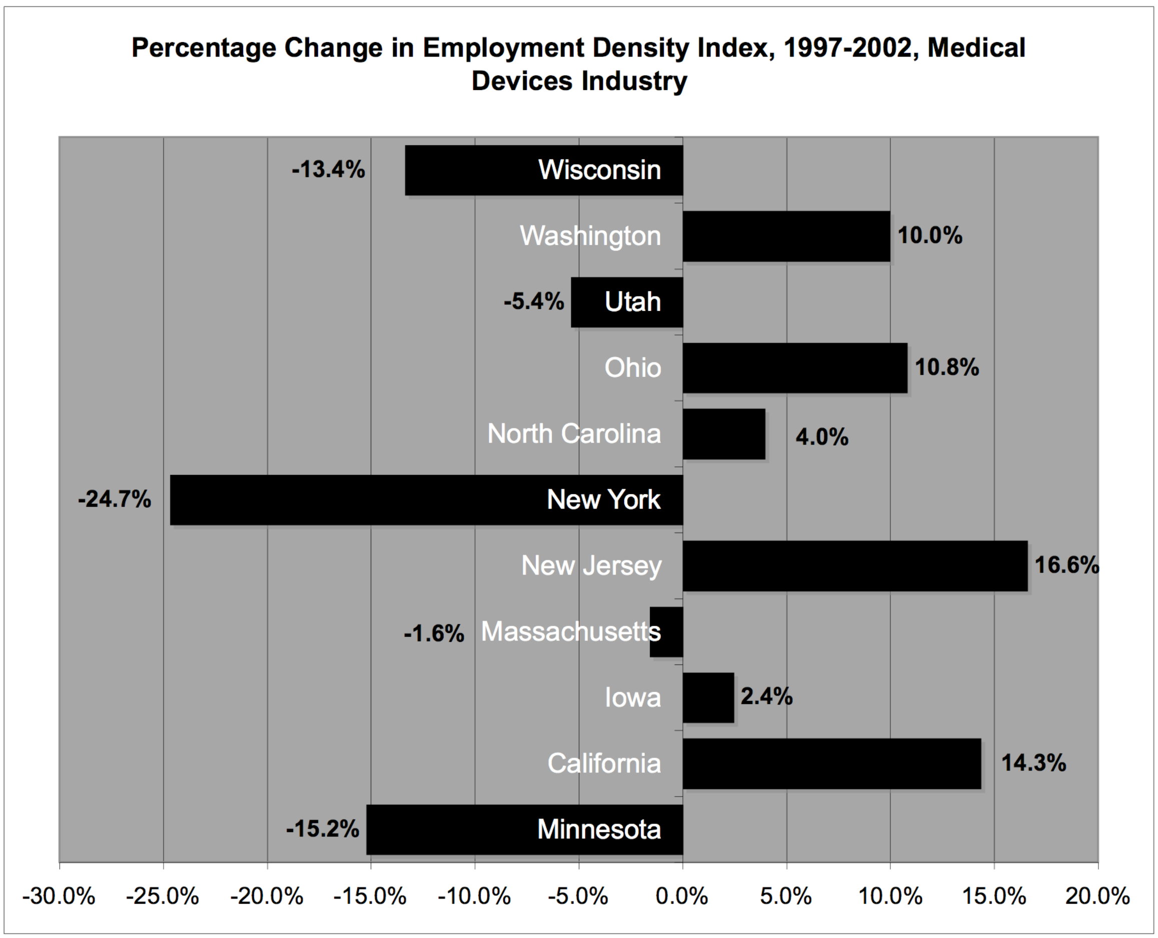
Figure 9



However, an "early warning sign" that Minnesota's competitiveness might be under threat is signaled by the fact that Minnesota's employment density index slipped from 3.09 to 2.62 over five years. Minnesota was not the only state whose employment generating efficiency in medical devices weakened during that period. Wisconsin and New York also declined. California, however, demonstrated an actual increase in employment-generating efficiency during that period – despite (or perhaps because of?) its already strong absolute position in medical devices. New Jersey, Washington and Ohio also exhibited advances.

Figure 10 takes the same data that were used to calculate Figure 9 but expresses each shift as a percentage change over five years from the base position of each state in 1997. This graph may be useful for helping policy makers to identify which states might be doing "something right" to improve their competitive position in medical devices, and which states might be "getting behind in the game." The states positioned on right hand side of the graph are improving their game, while the states positioned on the left hand side of the graph may be need to readjust their game plans. New York, Minnesota and Wisconsin appear to be in this latter group (and perhaps Utah's winning strategies from the past may be nearing the end of their utility). The scores on this graph may be seen, metaphorically, as the industrial equivalent of the canary in the mine that used to be taken underground by miners to warn themselves of impending danger should levels of toxic gas in the mine get too high. Being positioned on the left hand side of the graph may be seen as the equivalent of being in a mine tunnel when the canary falls off its perch! That does not mean that the miners will die … but, once the canary falls, it means they had better take fast action to improve their situation if they wish to retain careers in the mining industry!

Figure 10



It appears from the scores in Figure 10 that that **Minnesota may find some helpful positive lessons for its own future strategy by studying what has been going on during recent years in the medical devices industry, and its context, in: New Jersey, California, Ohio and Washington (and perhaps also North Carolina and Iowa).** Even though California is so much larger than Minnesota, the industry density measures reveal that there may still be some useful lessons to be learned from that state for Minnesota. In that same vein of logic, Minnesota may learn some valuable "what not to do" lessons by studying New York and

Wisconsin (and perhaps also Utah, and maybe also Massachusetts … although Massachusetts' decline is rather marginal, and any negative lessons learned might not be very pertinent).

Figure 11

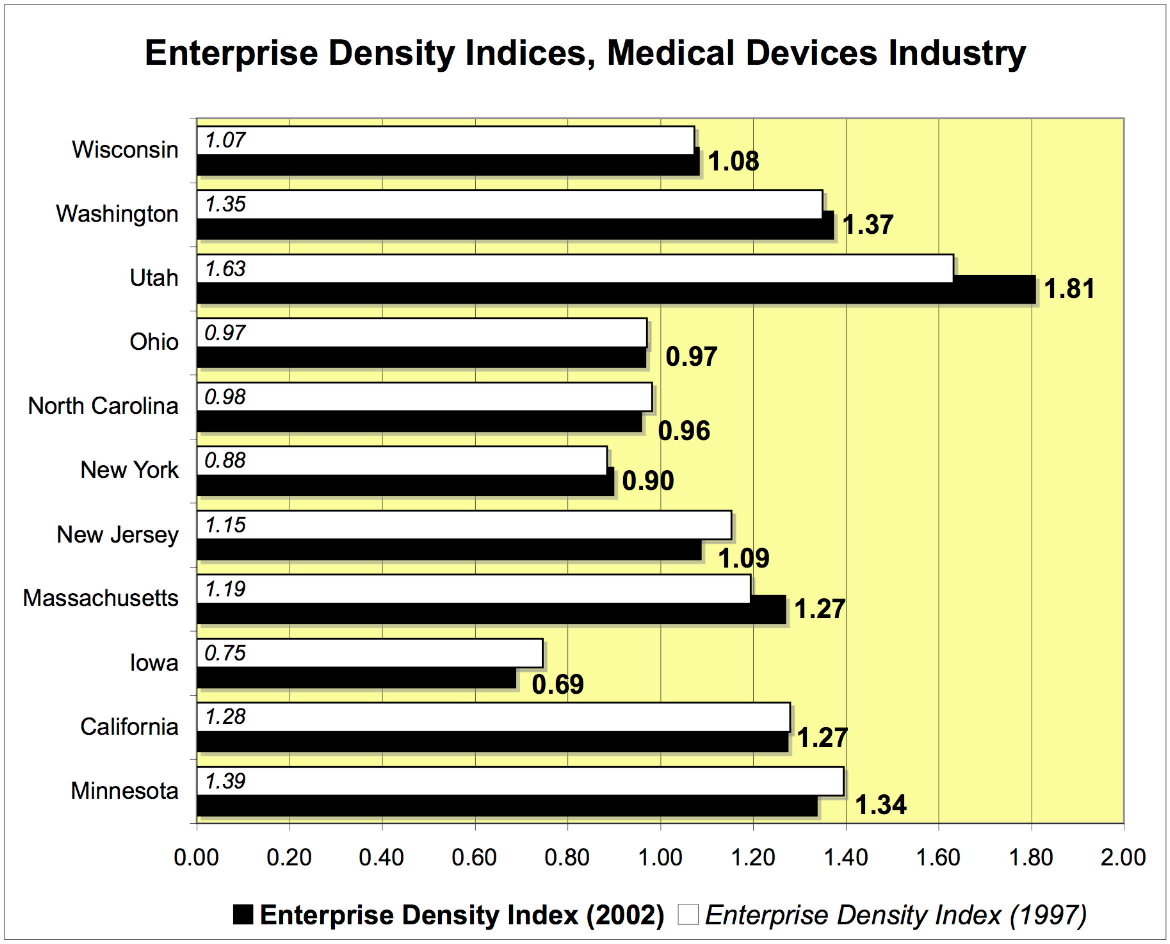


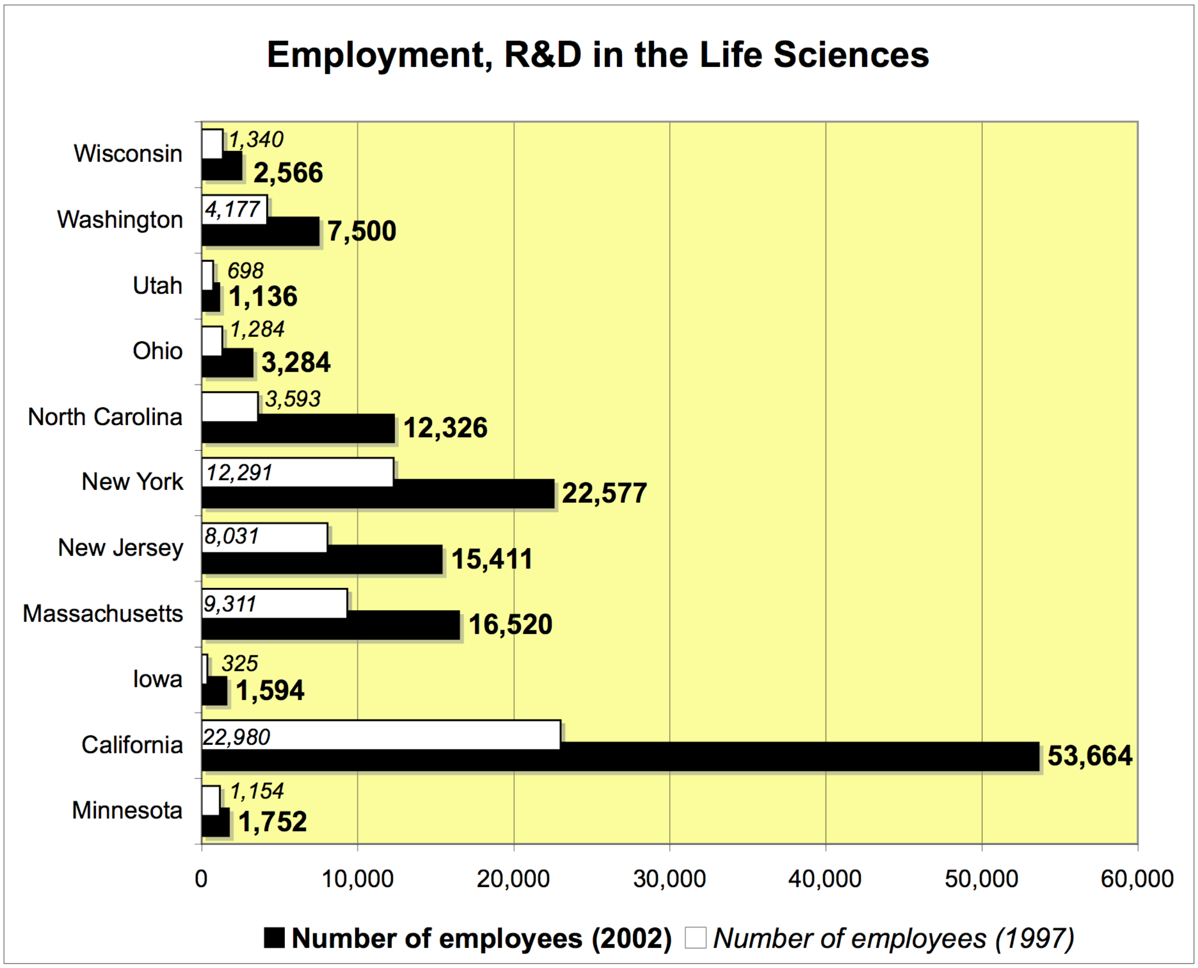
Figure 11 plots enterprise density indices for all eleven states (i.e., industry density indices using enterprises rather than employment as the industry factor) for 1997 and 2002. In effect, this graph reveals the relative efficiency of each state in generating enterprises in medical devices, and how their respective performance (i.e., entrepreneurial productivity) may have shifted over five years.

The contrasts between states in their productivity in generating and sustaining medical device enterprises are not as extreme as they are for employment generation in medical devices. Minnesota is also among the leading states by this measure, with only a marginal (and perhaps not very significant) decline over five years. Utah, it appears, has actually improved its efficiency in generating new medical device enterprises, despite a minor decline in its efficiency of generating new jobs (remember, in contrast with Minnesota, Utah still actually increased its total medical devices employment from 1997 to 2002, even though its efficiency of doing so decreased slightly). In short, the states which are both unusually productive in generating new medical device enterprises and which improved their productivity in doing so over half a decade, are Utah and Massachusetts (with Washington State also showing slight improvement). These were the leading new "entrepreneurial" medical devices states.

Emerging New Science-based Industries: Research and Development in the Life Sciences

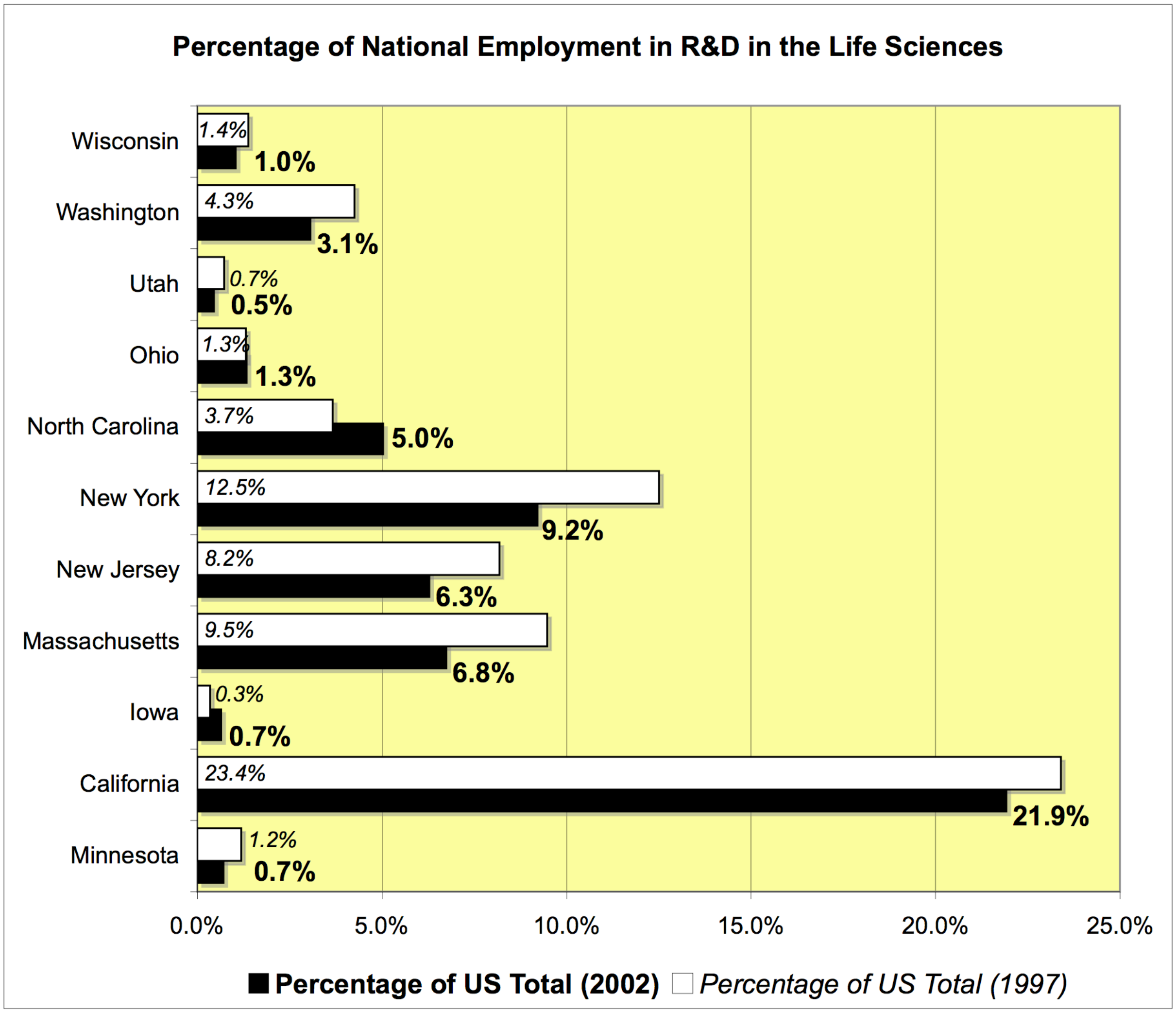
During the last three decades a new set of industries, based around new knowledge and new techniques emanating from the life sciences, have captured the attention of investors, policy makers, entrepreneurs, community development professionals and the public at large. Figure 12, using data taken from the U.S. Economic Census, graphs employment levels in this new industry domain across the same eleven states just reviewed for the medical devices industry.

Figure 12



In contrast with its historical leadership role in the medical devices industry, Minnesota is not a leading employer in the new life sciences industries. Of the eleven comparison states, only Iowa and Utah exhibit smaller absolute employment levels than Minnesota in R&D in the life sciences. Both of those states, furthermore, show significantly larger growth rates in life sciences R&D employment than Minnesota. In the five years to 2002 Minnesota's employment in the life sciences R&D industry grew by 52%, whereas Utah's grew by 63% and Iowa's grew by an astounding 390% from its relatively low starting point. It appears that, not only is Minnesota not a major player in life sciences R&D, but that its position may even be declining compared with other minor players.

Figure 13

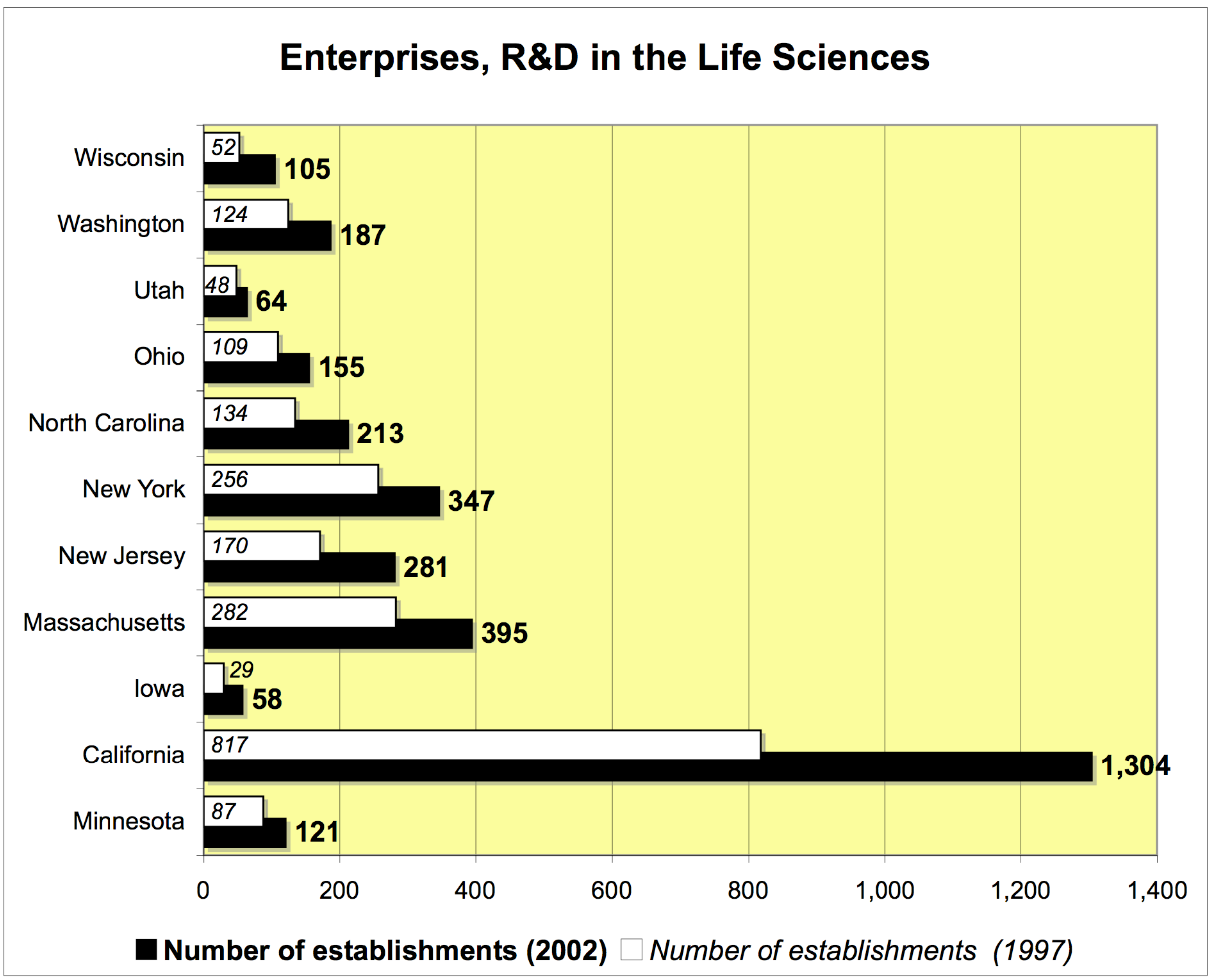


California, as was the case with medical devices, is also the overwhelming leader in life-sciences R&D employment. The number of new jobs alone (over 30,000 employees) that California created in this field over the five years to 2002 is significantly greater than the total 2002 employment levels of any other state. California's life sciences R&D enterprises ended the five-year growth period with almost 54,000 employees. Other prominent, and leading, states include: New York, Massachusetts, New Jersey, North Carolina and Washington. Of the prominent competitor states, North Carolina in particular has exhibited especially impressive growth, with an increase in life sciences R&D employment of over 240% in five years. Minnesota's neighbor, Wisconsin, managed to widen its lead over Minnesota during the period covered by Figure 12 from a 16% edge to a 46% percent edge. Minnesota did increase its employment in this field during that period, but not as much as its competitor states.

Figure 13 takes the same data that were used to construct Figure 12 but expresses them as a percentage of the national total, rather than as absolute employment numbers. California still appears as the overwhelming leader, even though its share of the national total dropped slightly over five years as other states invested heavily in the biosciences. Minnesota's share of the national total dropped from 1.2% to 0.7 percent. The two particularly interesting states illustrated in Figure 13 are North Carolina and Iowa, the only two states out of eleven that actually increased their share of the national total. Iowa started the period with one-quarter of Minnesota's share of the national total but ended the period equal with Minnesota. North Carolina increased its share of the national total by 1.3% (which was a 35% growth over its share in 1997).

There are 39 states not explicitly addressed in the figures (plus Washington, D.C.). The total number of people employed in "R&D in the life sciences" throughout the US in the other states increased sufficiently from 1997 to 2002 that the percentages in Figure 13 could drop, even though the absolute numbers (in Figure 12) increased.

Figure 14



The density indices take in to account what is happening in all U.S. states, not just what is happening in the 11 selected states. Interestingly, the same rough pattern appears in Figure 15 as appears in Figure 13. Hence, we can conclude that there has indeed been a substantial overall increase in nationwide employment in "R&D in the life sciences," including states other than the eleven that are the focus for this study. This is confirmed by the numbers in Appendix 5: the 2002 level of U.S. national employment in "R&D in the life sciences" is about 250% of the 1997 level. In contrast, the 2002 level of employment in Minnesota "R&D in the life sciences" is only about 150% of the 1997 level. Minnesota is growing more slowly than the nation as a whole in "R&D in the life sciences" employment.

It is also important to examine the relative position of states in generating new life sciences R&D *companies*, in addition to total *employment* – in other words, to analyze the relative entrepreneurial propensities of the states. Figure 14 was produced for this purpose. Figure 14 reveals that Minnesota fairs slightly better in the generation of life sciences R&D enterprises than it does in the generation of employment in that field. However, it is still fairly low on the list of competitor states. Furthermore, of the several states in the list of eleven that may be considered as Minnesota's "third tier" peers – Ohio, Wisconsin, Utah and Iowa – the majority grew more strongly than Minnesota from 1997 to 2002. Only Utah increased by a smaller percentage than Minnesota.

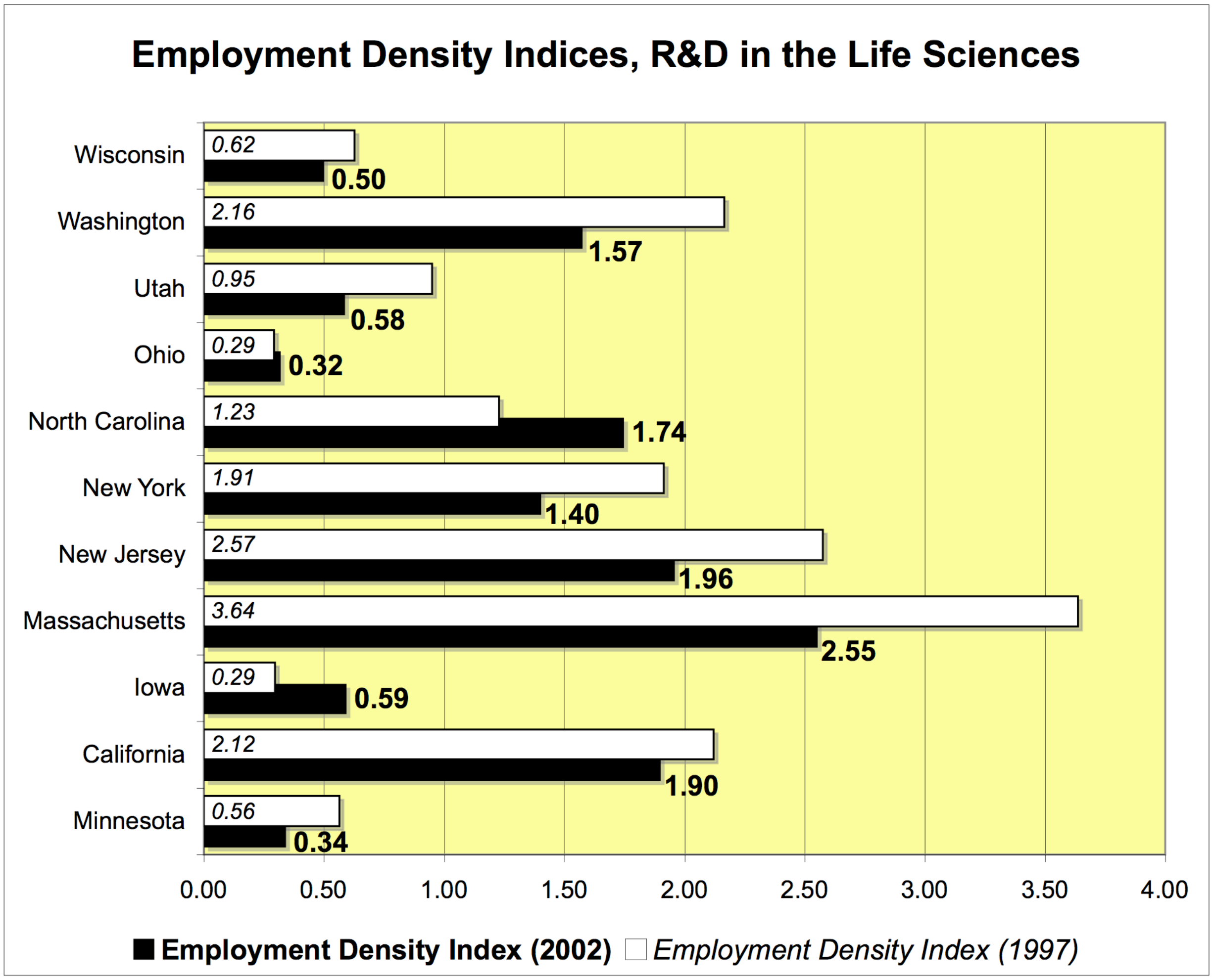
California, once again, appears as the front-runner, with over 1,300 life sciences R&D enterprises by 2002, compared with 121 in Minnesota. Massachusetts, New York, New Jersey and North Carolina – and also, running close behind, Washington – have emerged as strong entrepreneurial states behind the lead set by California. New York appears as a strong entrepreneurial state (behind California) in *both* the medical devices industry (Figure 6) *and* the life sciences R&D industry (Figure 14). In addition, New York, New Jersey and Massachusetts all occupy strong "second tier" positions behind California in employment generation for *both* the medical devices industry (Figure 5) *and* the life sciences R&D industry (Figure 12). **The leading (and apparently strengthening) positions of California, New York, Massachusetts, and New Jersey in *both* industry domains – medical devices and life sciences R&D – prompts the question of whether there is some kind of technological synergy at work here that these states are able to harness for both entrepreneurship and employment generation.**

These several leading states all have much larger populations and economies than Minnesota so, if there was a "flat playing field," we would expect these states to out perform Minnesota in terms of the absolute numbers of jobs and enterprises in life sciences R&D and in medical devices. It is therefore appropriate to weight the data in Figures 12, 13 and 14 to take in to account the relative sizes of each region vis-à-vis each other's economies and the national economy. Figures 15 and 16 accomplish this by representing the industry density indices of each state, for employment (Figure 15) and enterprises (Figure 16). The formulae for calculating these density indices are the same ones that were used to calculate the density indices for the medical devices industry, as explained above.

The employment density indices for the life sciences R&D industry (see Figure 15) reveal that, of the eleven states analyzed, the following are competitive on a national scale (in descending order of competitiveness): Massachusetts, New Jersey, California, North Carolina, Washington, and New York. Each of these states scores an employment density index of 1.0 or greater. Of these, North Carolina is the most intriguing, because it is the only one among the six competitive states that managed to increase its employment density in life sciences R&D during the five years to 2002.

Minnesota finished the five-year period near the bottom of the list of eleven with an employment density index of 0.34, marginally above Ohio. Even though Ohio (0.32) scored the lowest employment density index out of group of states, it outperformed Minnesota in one sense – in that its employment density index grew slightly from 1997 to 2002, whereas Minnesota's index actually shrunk. In short, Figure 15 shows that even when the figures are weighted to take in to account the relative sizes of the economies in each state (i.e., to create a "level playing field" for evaluating the relative performance of states in generating employment in life sciences R&D), Minnesota still appears to be a low performing state compared with its peers. California, while not as strong as Massachusetts when the employment figures are expressed as density indices rather than as absolute values, is still very competitive. In other words, California (with an employment density index of 1.9) still generates much higher levels of employment than one would expect, all things being equal, in the life sciences R&D industry.

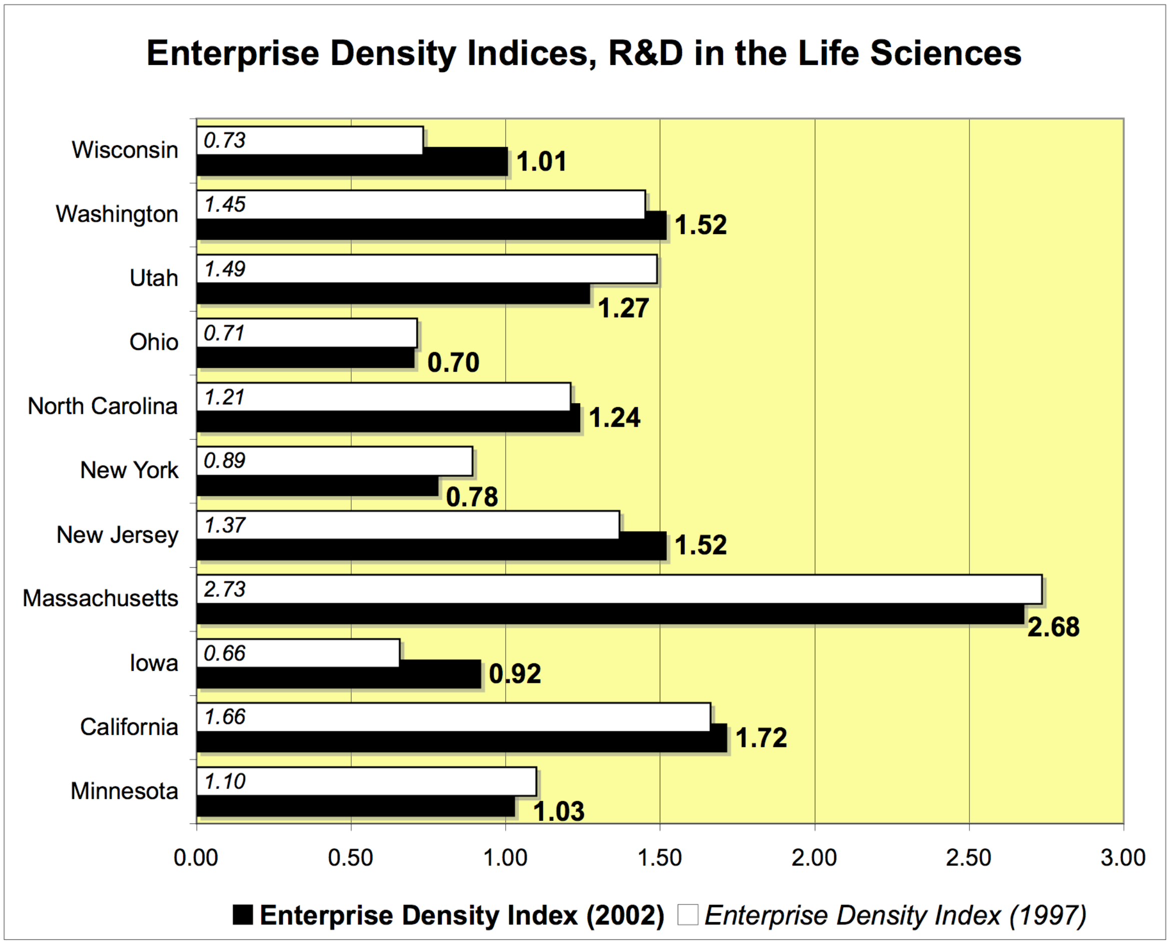
Figure 15



What about the competitiveness of each state in generating *enterprises* in the life sciences industry, weighted to adjust for the size of each state's economy? The enterprise density indices (what we might informally call the "entrepreneurship quotients") in Figure 16 help us to address this question. Figure 16 shows that, by this measure, Minnesota actually does quite well. **In 2002 Minnesota scored an enterprise density index for R&D in the life sciences of 1.03, which means that Minnesota performs at about the level one would expect, all things being equal.**

It seems that in the field of life sciences R&D entrepreneurship Minnesota's "children" are not "all above average" as years of listening to *Prairie Home Companion* might lead us to hope … rather, they are just average! … they are not outstanding, but they are definitely O.K. (so long as one does not look too closely at the employment figures behind the enterprise figures).

Figure 16

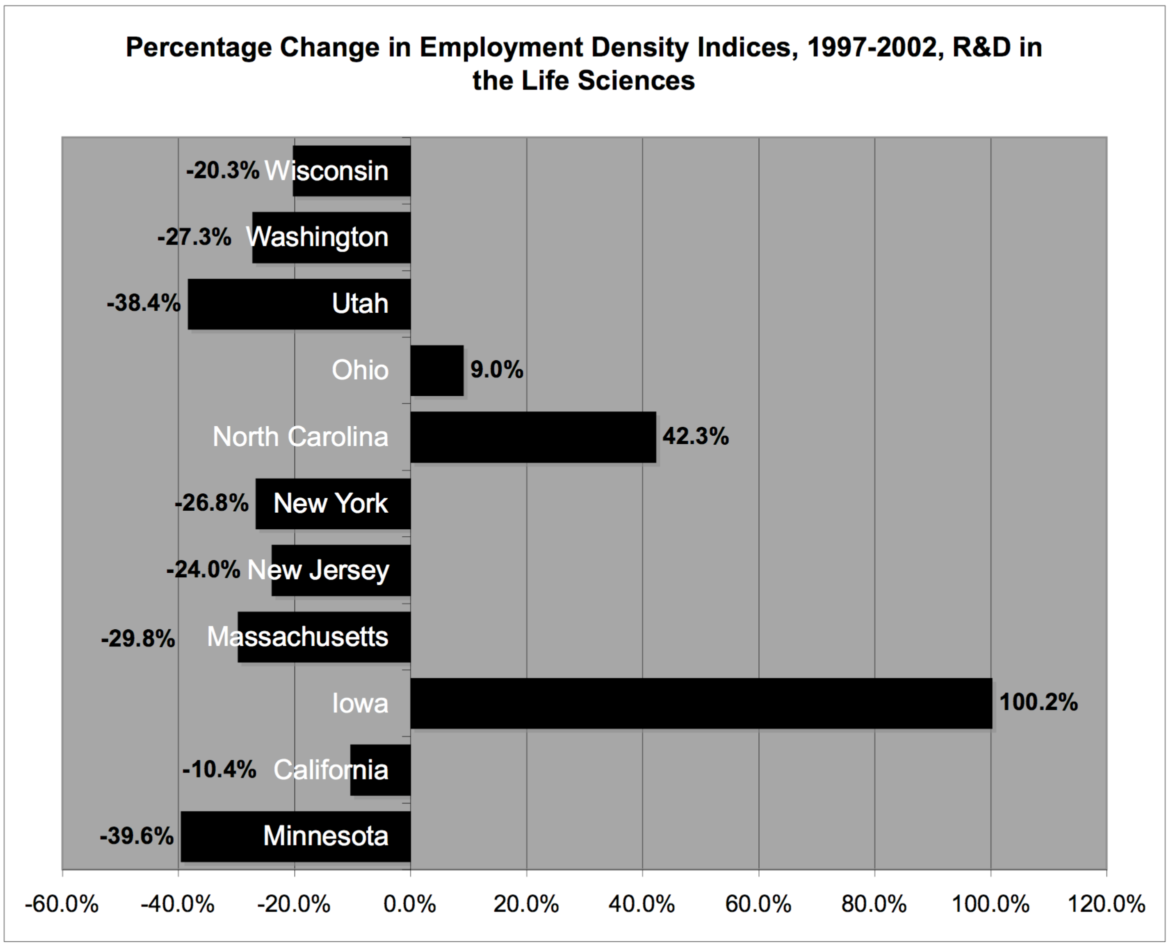


The competitive states, in terms of life sciences R&D entrepreneurship in 2002, are (in descending order of competitiveness): Massachusetts, California, New Jersey, Washington, Utah, North Carolina, Minnesota, and Wisconsin (by a "hair"). Of these eight states only five (California, New Jersey, Washington, North Carolina and Wisconsin) actually improved their entrepreneurial competitiveness over the five years to 2002. The biggest jump occurred with Wisconsin, which managed to achieve a 38% growth rate (calculated over five years) in its index from its 1997 level. In contrast with Minnesota, Wisconsin managed to switch from being a member of the "less than competitive" group to the "competitive" group during that time.

Iowa is another interesting state, in terms of entrepreneurship in life sciences R&D. Iowa, which by 2002 was still in the "less than competitive" group (i.e., it scored an enterprise density index of less than 1.0), managed to experience a 39% growth rate in its enterprise density index from 1997 through the following five years. It appears that Iowa may be a state to watch in coming years vis-à-vis life science R&D entrepreneurship.

As we saw in the case of the medical devices industry, changes in the level of a state's industry density indices over time may provide a very powerful tool for differentiating between states that are "doing something right" versus those that may be "underplaying their game," but unable to see that that is the case due to their relatively strong performance in the short term. Careful analysis of these indicators can provide a kind of early warning system of either impending "sleeper" problems – analogous to the canary in the mine falling off its perch – or even of unexpected future success, as the case may be. Figure 17 was designed to play that role for the life sciences R&D industry.

Figure 17



Of the six states we previously classified as being competitive in the generation of life sciences R&D employment (Massachusetts, New Jersey, California, North Carolina, Washington, and New York) only one (North Carolina) appears on the right hand side of the chart. This does not mean that the other five are no longer competitive. Rather, it means that their level of productivity in generating life sciences R&D jobs actually declined, even if the number of life sciences R&D jobs increased during that time period. Figure 17 tells us that **North Carolina is probably doing something especially effective in creating the right conditions for future life sciences R&D employment growth.**

Iowa and Ohio, even though they were part of the "less than competitive" group at the time the data were collected, were almost certainly doing something very effective to improve their relative position as locations for the life sciences R&D industry. Figure 17 suggests that Minnesota may do well to study the strategies of Iowa, North Carolina and Ohio should it wish to gain insights about powerful ways to improve its competitive position in the generation of employment in the emerging life sciences R&D industry. Given that these three states also appeared on the right hand side of the equivalent graph for the medical devices industry (Figure 10), the chances that Minnesota may gain valuable policy insights by studying the strategies and conditions of North Carolina, Iowa and Ohio, are quite high. It looks like these three states might be breeding the next generation of "all above average" life sciences R&D children.

What about Minnesota? It appears that while Minnesota is performing as well as might be expected under the circumstances, in the generation of life sciences R&D *enterprises* (i.e., Minnesota is a respectable state vis-à-vis life sciences R&D entrepreneurship), it is underperforming in the generation of *jobs* within this industry. In addition, Minnesota's overall level of *productivity* in generating both employment and enterprises in the life sciences R&D industry shows signs of weakening over the five years to 2002. **Minnesota has no grounds for being complacent regarding its future position in research and development within the life sciences**. In fact, as we have seen from the data in the above figures, there are reasons to be concerned.

Minnesota's Competitive Position in the Whole Biobusiness Technology Industries Sector

Having now reviewed Minnesota's position in its traditional stronghold, medical devices, and in the emerging competitive industry, life sciences R&D, let's return our attention back to the overarching topic of this study, the whole interdisciplinary domain of biobusiness technology.

Figure 18

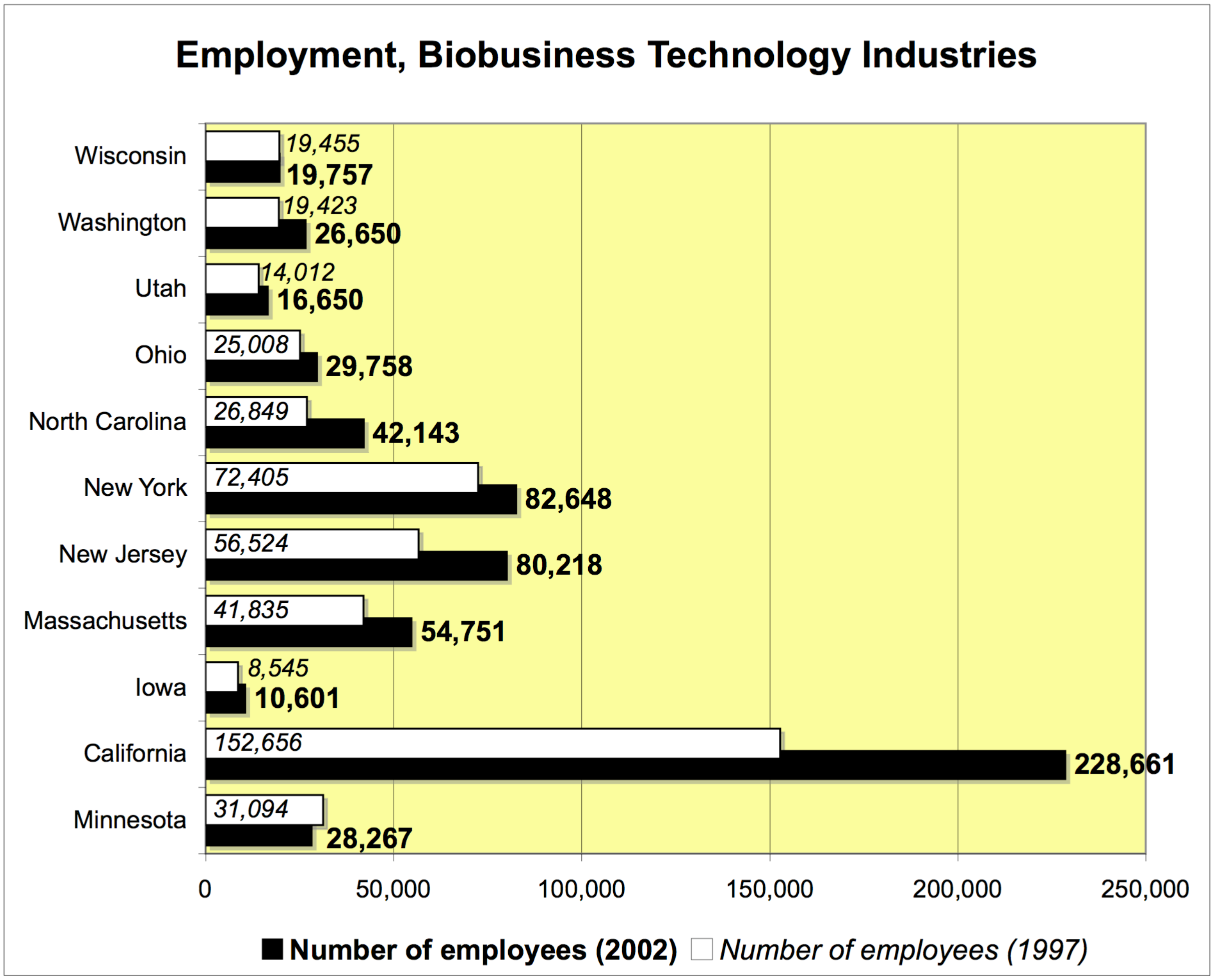


Figure 18 plots the total employment level for biobusiness technology enterprises (defined using the NAICS codes as proxies) in the eleven states that have been the focus of our analysis thus far. California clearly leads the nation in biobusiness technology, approaching nearly a quarter of a million employees in biobusiness technology enterprises by 2002! Over 76,000 of these jobs were added during the preceding five years alone.

California is followed in the distance by several second tier states vis-à-vis biobusiness technology employment: New York, New Jersey and Massachusetts. Interestingly, these are the same states that dominate the second tier for employment in life sciences R&D (and also the second tier for employment in the medical devices industry – with the caveat that Minnesota is also a dominant second tier player in medical devices).

A sobering observation for Minnesota, from Figure 18, is that Minnesota was the only state out of eleven that actually appeared to lose biobusiness technology industry employment during the five years from 1997 to 2002 (a decline from over 31,000 employees in 1997 to just over 28,000 employees by 2002). Fortunately for Minnesota, however, the state does appear to have recently reversed this negative trend (as suggested by the data in Tables 3 to 5). Nevertheless, by 2002 Ohio and North Carolina – who shared the third tier with Minnesota – were both ahead of Minnesota in total biobusiness technology industry employment … and Washington was very close behind (and catching up).

Figure 19

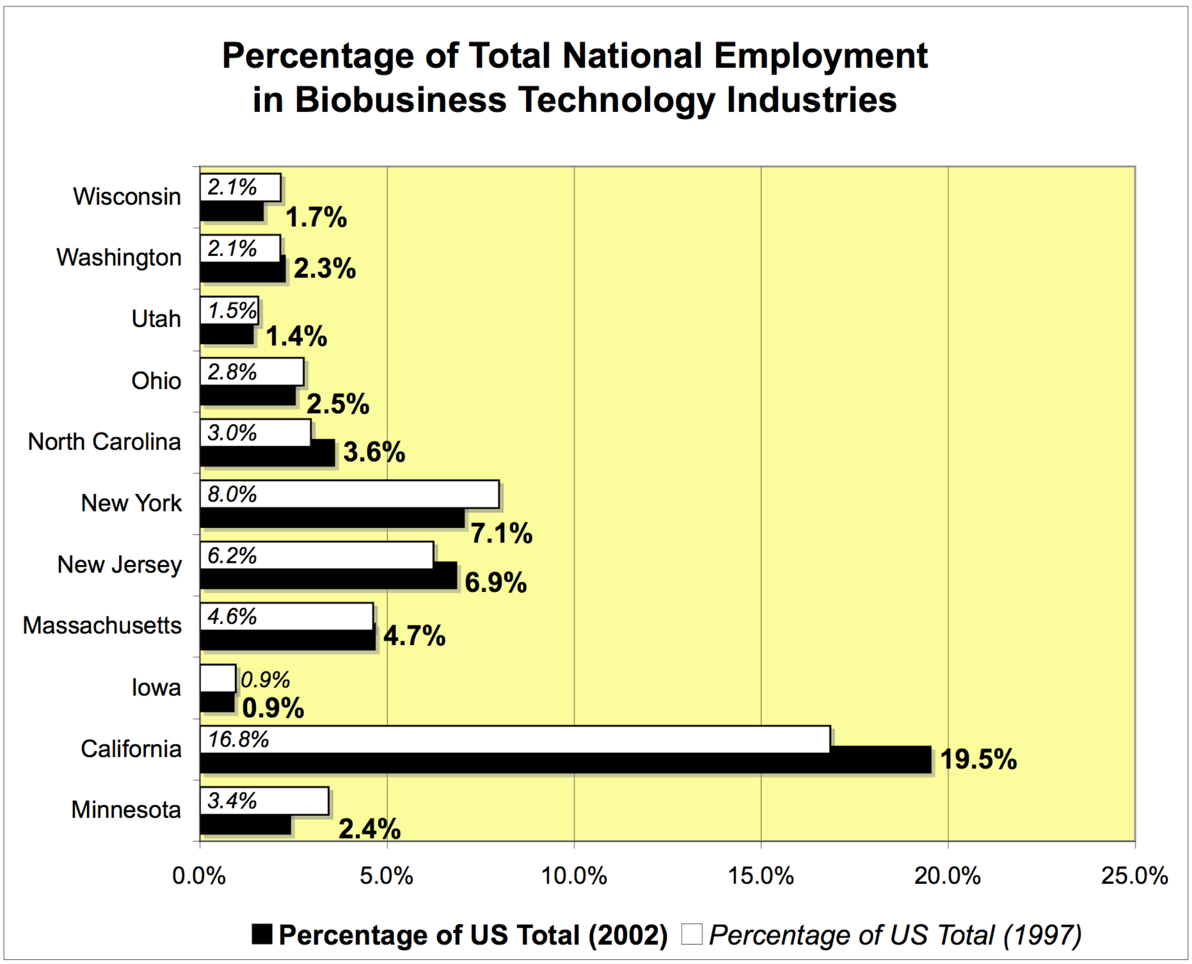
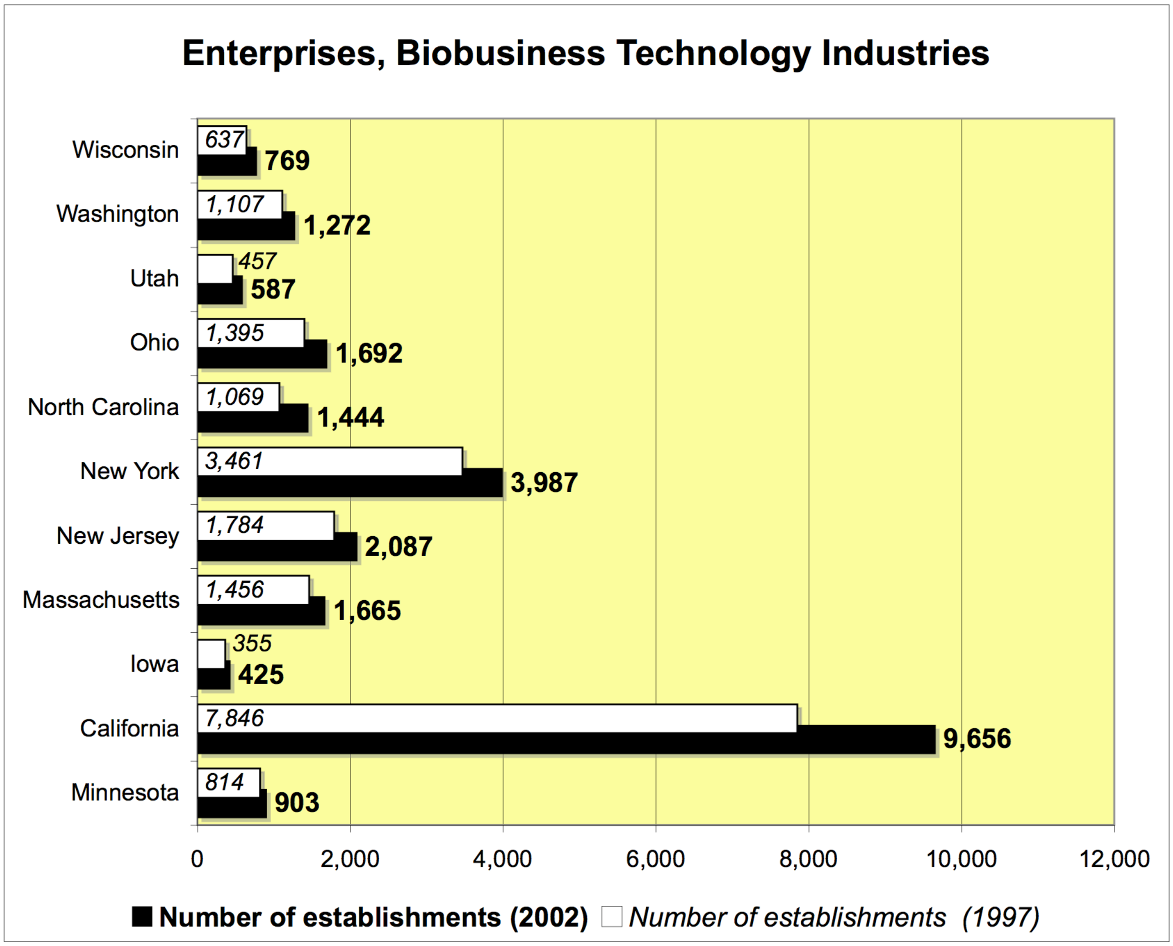


Figure 19 takes the same data that were used to construct Figure 18 but expresses them as a percentage of the national total, rather than as absolute employment numbers. California once again is the overwhelming leader; and (as was the case with medical devices, but unlike the case with life sciences R&D) California's share of total national biobusiness technology industry employment actually increased over five years, despite stiff competition from other states. Minnesota's share of the national total dropped from 3.4% to 2.4 percent. Of the strong second tier states, New Jersey managed to slightly increase its share of the national employment total.

As was the case with medical devices and life sciences R&D, it is also important to examine the relative position of states in generating new biobusiness technology *companies*, in addition to total biobusiness technology *employment* – in other words, to analyze the relative *entrepreneurial propensities* of the states in biobusiness technology. Figure 20, which was produced for this purpose, reveals that Minnesota has performed much better in the generation of biobusiness technology enterprises than it has for the generation of biobusiness technology employment. The number of biobusiness technology enterprises in Minnesota increased by almost 90 during the five years from 1997 to 2002. Minnesota's rank did not change during that period; but it is unfortunately still fairly low on the list of competitor states. Out of the eleven comparisons states, only Wisconsin, Utah and Iowa were home to less biobusiness technology enterprises than Minnesota by 2002.

Figure 20



California leads the pack yet again as the sole first tier state, with over 10,000 biobusiness technology enterprises by 2002, compared with 903 in Minnesota. New York stands apart as the sole second tier state, being home to almost 4,000 biobusiness technology enterprises in 2002. The third tier is more evenly spread, with New Jersey, Massachusetts and Ohio appearing strong; and with Washington and North Carolina (each exhibiting significantly more than a thousand biobusiness technology enterprises) positioned not too far behind their peer third tier states.

Besides these observations about the relative rankings of the eleven states, it is apposite to observe that none of those states actually reduced their number of biobusiness technology enterprises during the five years to 2002. All continued to create new enterprises, even if the increases were marginal in some cases. **Biobusiness technology, as a broad domain, appears to be an area in which entrepreneurship continues steadily in all the states reviewed here**.

The fact that the pattern of biobusiness technology enterprise creation among states is more diverse and multi-tiered compared with the inter-state pattern of enterprise creation in medical devices and life sciences R&D, suggests one important theme: in the wider domain of the biobusiness technology there appears to be more room for new competitive positions to be established and rearranged between states than is the case with the other more narrowly defined industry domains. Perhaps there is more room in the biobusiness technology industry sector for states to affect their competitive position through the sophisticated application of strategy.

Figure 21

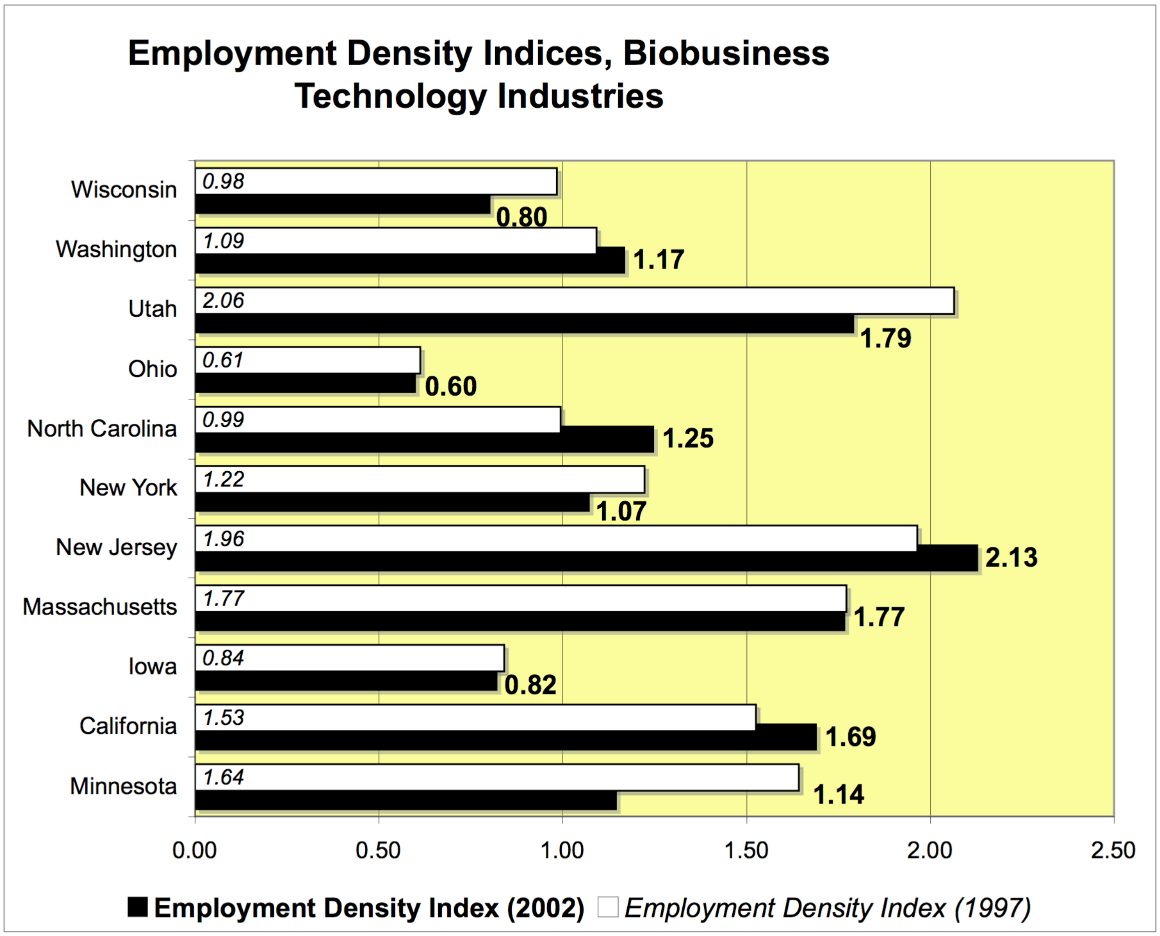


Figure 21 plots the biobusiness technology employment density indices for Minnesota and the ten other states. **The good news for Minnesota is that, from the point of view of employment generation, as opposed to enterprise generation, Minnesota is one of the states exhibiting above average levels of competitiveness** (i.e., it scored an employment density index of greater than 1.0). The competitive states, in descending order of productivity in generating biobusiness technology jobs in 2002, are: New Jersey, Utah, Massachusetts, California, North Carolina, Washington, Minnesota, and New York. **The unsettling news for Minnesota, however, is that Minnesota's biobusiness technology employment density index actually dropped significantly**, from 1.64 in 1997 to 1.14 in 2002.

Figure 22

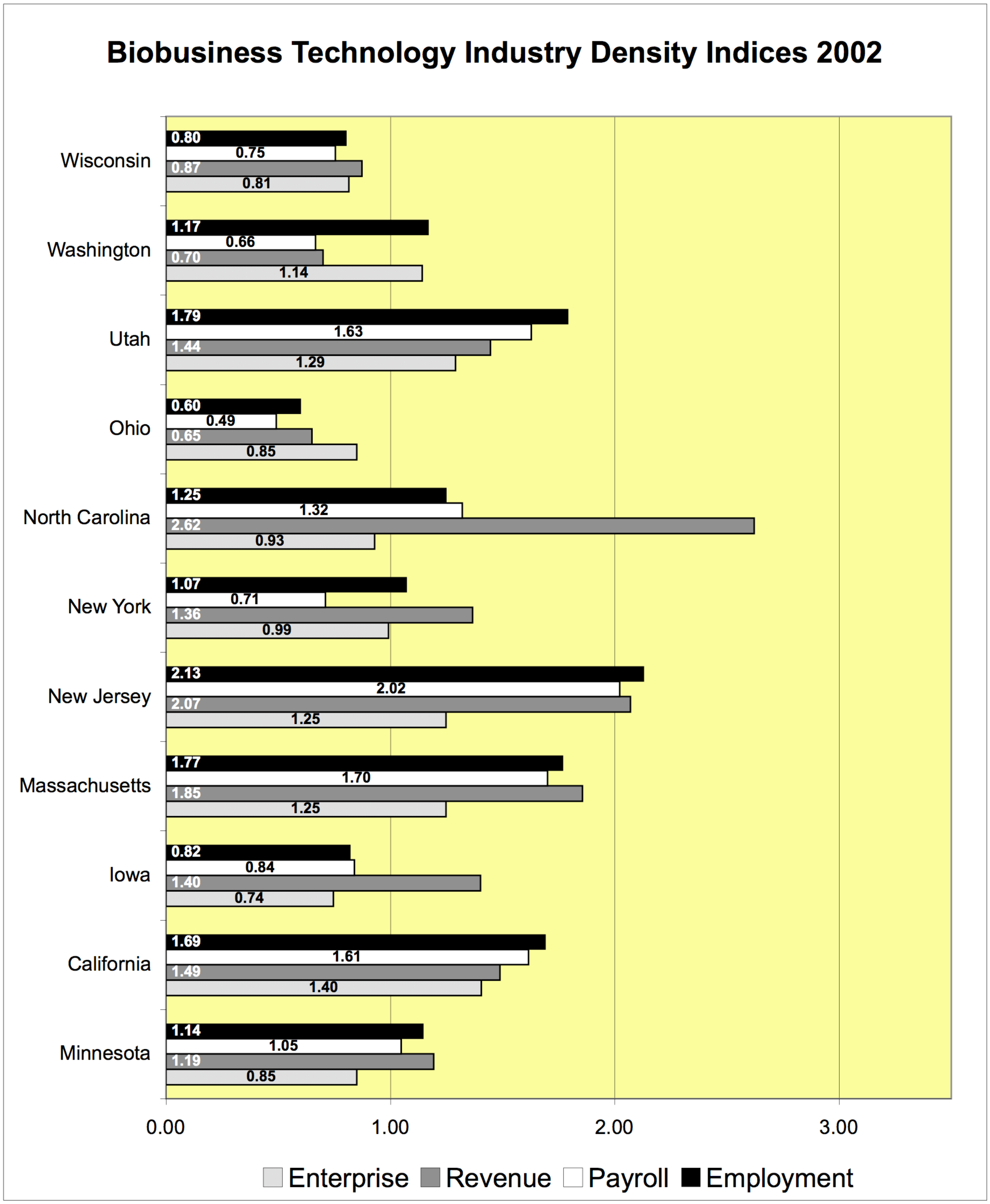


Figure 22 plots the density indices for biobusiness technology enterprises for the eleven competitor states. The graph shows that not only does California lead in the absolute level of biobusiness technology entrepreneurship, but it also leads on a density basis, with an enterprise density index of 1.4 in 2002. California has apparently earned its position, with above average performance. The other competitive states (i.e., the states exhibiting biobusiness technology industry density indices greater than 1.0) are, in descending levels of competitiveness: Utah, New Jersey and Massachusetts (equal, 1.25), and Washington. Despite its commanding lead over other states (with the exception of California) in its total number of biobusiness technology jobs, New York's productivity in generating biobusiness technology enterprises is about what one would expect, all things being equal. In other words, New York is about average, nationwide, in the generation of enterprises in this combined set of fields.

Minnesota's position as a generator of biobusiness technology enterprises is, according to Figure 22, below average (enterprise density index for 2002 = 0.85). Unfortunately, this lackluster performance has a further shadow cast over it by the fact that Minnesota's enterprise density index actually dropped over five years from its previous level of 0.91. This is not a precipitous decline, by any means, but it is a serious cause for concern.

Figure 22 plots the industry density indices for all eleven states, during 2002, for four different industry factors: employment (also plotted in Figure 19), enterprise (also plotted in Figure 20), revenue, and payroll. Figure 22 is similar to Figure 8, except that it represents the *whole biobusiness technology industry* sector rather than just the *medical devices industry*.

Minnesota is competitive (i.e., exhibits above average productivity in generating activity in the biobusiness technology industry) from the point of view of employment, revenue and payroll, but (as was already discussed above) has fallen behind in its productivity in generating biobusiness technology enterprises.

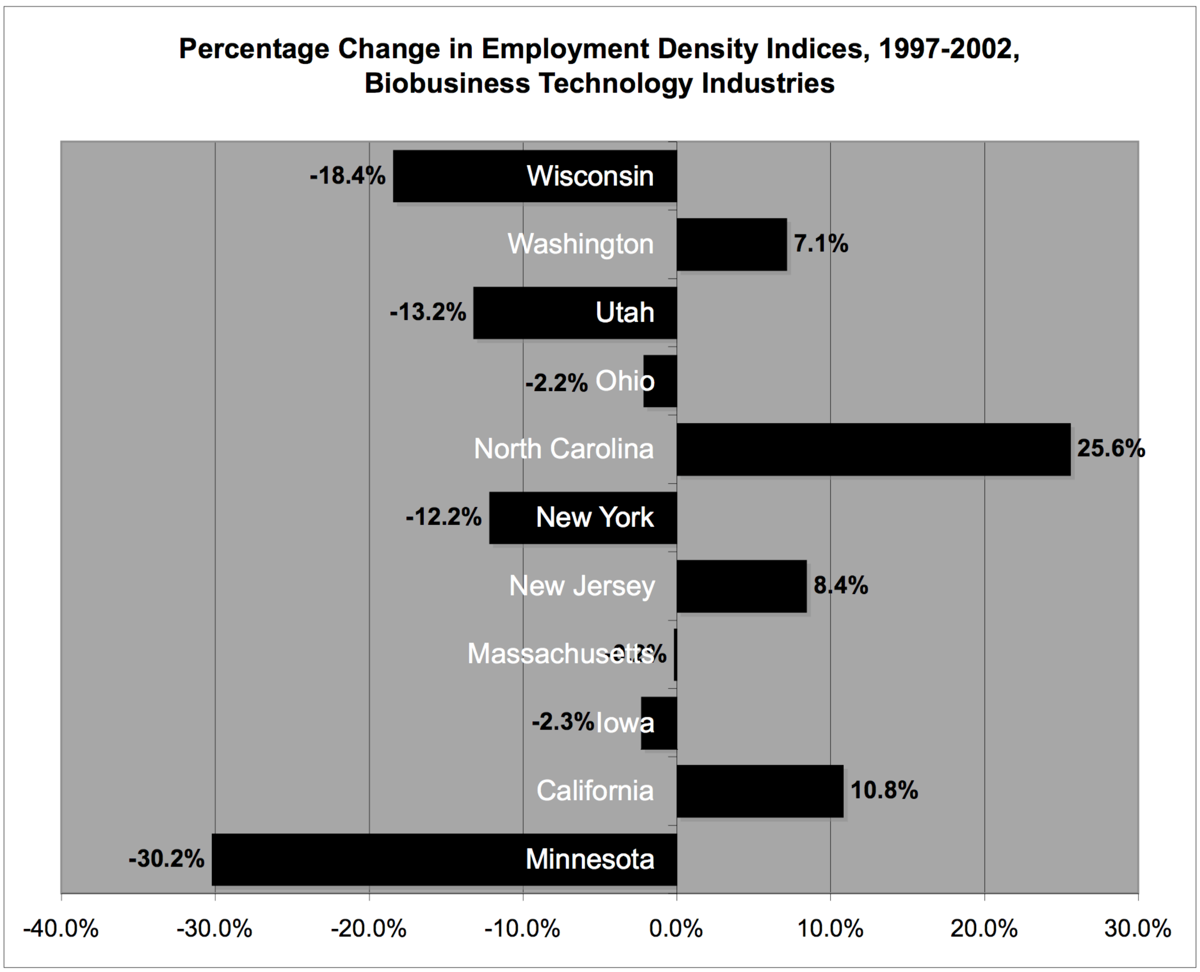
When all four industry factors are used to calculate industry density indices for the whole biobusiness technology sector, some interesting results emerge. North Carolina is extraordinarily strong in generating revenue from biobusiness technology activities. New Jersey and Massachusetts follow next with aggregate financial performance that is, despite being lower than that of North Carolina (adjusted for the size of the economy), very impressive indeed. This evokes the question of whether the relatively high biobusiness technology competitiveness of these states might be amplified over time through internal reinvestment of their relatively high financial returns. An early lead, as expressed in high industry density indices, may become self-reinforcing over time. **This may be a challenge for Minnesota to address in the near future**.

Figure 22 reveals that only four out of eleven states (New Jersey, Utah, Massachusetts, and California) have managed to achieve nationally competitive positions (i.e., industry density index scores of above 1.0) for all four industry factors (employment, enterprise, revenue, and payroll). These four states appear to exhibit relatively robust biobusiness technology competitiveness profiles.

Figure 22 also reveals that while Minnesota's competitiveness performance overall in the biobusiness technology is generally respectable (i.e, mixed, depending upon the factor, but about average overall, when all factors are taken in to account), it is nevertheless one of only two states that managed to score three out of four industry density indices above 1.0 during 2002. The other was North Carolina. **This may be taken to imply that Minnesota has sufficient basic strength in biobusiness technology that, if it manages to develop and implement powerful and sophisticated strategies in the near future, it might be able to lift itself from a mediocre position to one of national prominence in the industry.**

Figure 23 takes the same data that were used to calculate the employment density indices in Figure 21 but expresses each shift as percentage change over five years from the base position of each state in 1997. In the same way that we looked to similar graphs as "canary on the perch" indicators for states in the medical devices industry and the life sciences R&D industry, this graph may be useful for helping policy makers to identify which states might be doing "something right" to improve their competitive position in biobusiness technology, and which states might be "getting behind in the game." The states positioned on right hand side of the graph may be interpreted as doing a good job of improving their game, while the states positioned on the left hand side of the graph may be interpreted as needing to readjust their game plans for the biobusiness technology industry.

Figure 23



We can see from Figure 23 that, of the eleven states examined in this study, North Carolina exhibits the most dramatic underlying shift in its competitive position in the biobusiness technology industry in the United States, over the five years to 2002. California, New Jersey and Washington also appear on the right hand side of the graph, suggesting that there are positive strategic lessons to be learnt from examining their situations.

Conversely, although Minnesota is not alone in experiencing a drop in its competitive position in biobusiness technology employment during the five years to 2002, the scale of Minnesota's decline (measured as a rate of change from the 1997 level) is the most noticeable of all the states on the "getting behind in the game" side of the graph. It looks as if Minnesota's biobusiness technology "canary on the perch" has stopped chirping and is beginning to sway a little. It's time to look for the source of the gas leak in the biobusiness technology mine, before the canary falls off its perch.

Conclusions

The analysis of standardized national economic data from the U.S. Census Bureau presented in this report has confirmed the widespread belief among informed observers and residents of Minnesota that Minnesota is indeed a major national player in the U.S. medical devices industry. Minnesota and Massachusetts were roughly equal second as locations for medical devices industry jobs in 2002; but both trailed way behind the national leader, California.

When it comes to creating medical devices companies, rather than jobs, Minnesota is solid, being home in 2002 to 2.6% of the nation's medical devices establishments. However, it lags behind quite a few other states in medical devices entrepreneurship (creation of new enterprises based on medical devices).

When the data on the medical devices industry are weighted to take in to account the relative sizes of the economies of each state, using density indices rather than absolute numbers as indicators, Minnesota shines as a very competitive location … significantly more productive than California in generating medical devices jobs, given the relative size of the resource base of each state.

Unfortunately, a number of shadows hang over Minnesota's historical strength in medical devices. Firstly, the state actually lost jobs in the medical devices industry from 1997 to 2002, during a period when most of its competitors were gaining jobs in the field. Secondly, Minnesota's overall competitiveness in medical devices – meaning its relative efficiency in generating jobs and enterprises in medical devices, taking in to account the size of Minnesota's economy compared with competitors – actually declined during the most recent five years for which data are available. This decline is indicated by a downward shift in Minnesota's medical devices industry density indices.

In short, while Minnesota remains strong in the medical devices industry, the state appears to be losing ground from the point of total medical devices employment, in comparison with other states; and its overall leadership position and competitiveness compared with other U.S. states appears to be eroding. Minnesota cannot afford to take the hoped-for future economic benefits of its medical devices industry for granted. If current trends continue unabated policy makers may be justified in wondering whether the history of the state in the field of main-frame computers might be repeated for medical devices. It is not too late. Minnesota is still competitive in medical devices. However, the economic indicators reviewed in this report should be interpreted as a call for action. It would be industrial suicide for Minnesota to rest on its medical devices laurels. The state needs to identify its strengths and vigorously cultivate them in the face of stiff interstate competition if it is to maintain its "golden apple" industry – medical devices – as a mainstay for the future.

Is Minnesota doing better in the development of new science-based, bio-related industries, to compensate for its eroding competitiveness in medical devices? This analysis of the emerging industries based around research and development in the life sciences revealed that Minnesota is a rather minor player in these new fields. Minnesota falls near the bottom of the list of the eleven states compared in this study as a location for R&D in the life sciences. This pattern holds true no matter whether the figures are expressed as absolute numbers or whether they are weighted to take in to account the relative size of each state's economy.

An even more unsettling fact for Minnesota emerged through the foregoing analysis: the state's competitive position in research and development in the life sciences actually declined during the period covered by this study; and this happened during a period when total employment in the field nationwide increased by about 150 percent. Unlike the historical role the state has played in the medical devices industry, Minnesota is in a weak position in the new science-based biology-related research industries.

In the wider biobusiness technology industry analyzed in this study Minnesota has performed a lot better as a state than it has in the new life sciences R&D industry fields. It appears that Minnesota has managed to leverage its underlying capabilities in medical devices and various fields of agri-bio and bio-industrial technology – in both the medical domains and the non-medical domains – to stake out a credible position in the technology intensive fields of biobusiness. With over 900 enterprises, over 28,000 employees, over $6.6 billion in annual revenues, and dispensing over $1.3 billion in payroll to Minnesota's citizens annually (in 2002), the biobusiness technology industry is a significant player in the state's economy. By 2005 total employment in biobusiness technology enterprises (excluding those hidden as units inside other corporations, universities, not-for-profit entities, or government agencies) had reached an estimated level of over 35,000 people.

Table 6
Overall Economic Trends, Biobusiness Technology Industries (and the Macro-economy), Minnesota, 1997-2002

Economic variable	Medical devices	R&D in the life sciences	Total biobusiness technology	All industries (the macro economy)
# of workers	Down slightly	Up	Down	Up
% of U.S. workforce	Down	Down	Down	Up
# of U.S. enterprises	Up slightly	Up	Up	Up
% of U.S. enterprises	Down slightly	Down	Down	Down slightly
Competitiveness	Down	Down	Down	Stable / up slightly

Compared with other states, Minnesota holds a very respectable, but not stellar, position. Minnesota is competitive in biobusiness technology. The state exhibits slightly above average productivity in generating employment, revenue and payroll, and slightly below average productivity in generating enterprises, in the biobusiness technology sector. Minnesota is less entrepreneurial in biobusiness technology than other states, even if its overall economic performance in the industry is competitive. Overall, when the figures are weighted to take in to account the relative size of the economy of each state and the overall level of the biobusiness technology industry at the national level, Minnesota performs a slightly better than one would expect, all things being equal. Minnesota is doing "O.K." at the aggregate level.

Minnesota's respectable performance in building a broad-based biobusiness technology industry is, however, mitigated – if one looks a little more closely at the numbers – by the fact that its relative competitiveness (measured by industry density indices) actually fell during the five-year time period covered by this study. In other words, Minnesota's efficiency at generating biobusiness technology industry activity compared with other states, and with the nation as a whole, has been eroding. If this trend continues it is highly doubtful that Minnesota will be able to command a leadership position in the vital new domain of biobusiness. The overall competitive situation of Minnesota's biobusiness technology sector, in comparison with the overall macroeconomic situation in the state, is summarized in Table 6.

For now, Minnesota is competitive in biobusiness, overall. However, in order to ensure a viable future for itself in biobusiness Minnesota will need to activate all its available resources and creativity, and build upon its exiting distinctive capabilities in biobusiness technology, at a quantum level above what it has been doing in recent years. The state will need to build upon its very real existing biobusiness technology strengths and forge a distinctive pathway ahead that exploits the wide variety of capabilities in the states across a diverse array of fields.

What can be done to ensure a competitive future for Minnesota in biobusiness? Making comparisons with other states, using aggregate industry categories like "medical devices," "pharmaceuticals," "life sciences," or "biobusiness," will only go so far. Analysis of these generalities produces little more than indicators that suggest how well the state is doing and in which general areas it needs to improve its performance. These indicators do not reveal **what** needs to be done and **how** it should be done. Getting answers to those kinds of questions would require a different kind of analysis – one that is more fine grained and attuned to the distinctive technological capabilities of the state and that would allow it to stand apart in the crowd rather than try to play catch-up with the crowd (on its back foot, while looking over its shoulder to see how well other members of the crowd are performing).

The economic indicators produced in this research project and summarized in this report are analogous, as was suggested earlier, to the old-fashioned safety indicators used by miners to alert themselves to the invisible danger of toxic gas in underground mines … canaries on perches. When the canaries died (being more sensitive to the gases than humans) the miners had the benefit of an advanced warning that danger was imminent. They had an opportunity to escape or take corrective action before the problem became too bad. However, the canaries were never a solution to the problem; they were simply indicators that a problem existed. The miners still had to do the hard work of identifying the source of the gas and then doing something effective in response, quickly. In short, they had to take stock of the advanced warning signal (the dead canaries) and move!

Likewise, unless Minnesota can quickly identify several fields of biobusiness technology in which it has a reasonable chance of being the best, or among the best, in the world, its chances of ensuring an internationally competitive position for itself in the biobusiness technology industry will be slim. That will require looking inwards to determine the state's distinctive capabilities, with depth and precision. That information cannot be found in standardized national databases, and through high-level national comparative analyses. It requires, instead, a ground-up approach, based upon carefully identifying all the organizational players in the industry – whether they are profit oriented corporations, units of larger not-for-profit organizations, service units of larger for-profit corporations, or not for profit organizations in their own right – followed by a careful mapping exercise using technological information generated directly from leaders in those organizations themselves.

Would that kind of work be difficult to do? Perhaps. Probably. It certainly would involve walking along the road less traveled. Can Minnesota afford to avoid the challenge of walking along that road, just because it is less traveled? … just because the risks of stumbling might be higher than they would be by walking along the well trodden high road? The results of this comparative competitiveness study, using standardized data (collected from the road more frequently traveled), suggest that the answer is "no." We cannot assume that Minnesota's relatively comfortable position from the past in medical devices and other industries will spontaneously continue in to the future, in the ever more complex and interdisciplinary technological world of biobusiness. The quantitative indicators at hand suggest that Minnesota's competitors pose serious threats to the state's position (not to mention anything about communities from elsewhere in the world … Europe, China, Japan, India, for example).

The citizens of Minnesota ought to start the challenging journey, along the road less traveled, earlier rather than quicker – despite having inadequate existing maps for guidance. New maps need to be drawn, and that can only be achieved by studying the local technological geography. Reading a national industry atlas may be instructive or inspirational, but it cannot lead to a better understanding of the local technological terrain and it cannot provide guidance about where one should place one's feet while walking!

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Appendix 1

Benchmarking of BioBusiness Technology Industries in Minnesota

Note: Data include both establishments with employees and establishments without employees

NAICS codes selected as proxies for each industry category

Medical devices

3391	Medical equipment and supplies manufacturing
334510	Electromedical and electrotherapeutic apparatus manufacturing
334517	Irradiation apparatus manufacturing

Pharmaceuticals

3254	Pharmaceutical and medicine manufacturing

R&D in the life sciences

5417102	Research & development in the life sciences

Agri-bio & bio-industrial technology

325193	Ethyl alcohol manufacturing
325221	Cellulose organic fiber manufacturing
311221	Wet corn milling
311222	Soybean processing
311223	Other oilseed processing
31212	Breweries
31213	Wineries

Biobusiness clinical services

622	Hospitals
54194	Veterinary services

Biobusiness technology (narrowly defined)

3391	Medical equipment and supplies manufacturing
334510	Electromedical and electrotherapeutic apparatus manufacturing
334517	Irradiation apparatus manufacturing
3254	Pharmaceutical and medicine manufacturing
5417102	Research & development in the life sciences
6215	Medical and diagnostic laboratories
325193	Ethyl alcohol manufacturing
325221	Cellulose organic fiber manufacturing
311221	Wet corn milling
311222	Soybean processing
311223	Other oilseed processing
31212	Breweries
31213	Wineries

Biobusiness (broadly defined)

Biobusiness technology (narrowly defined)
+
Biobusiness clinical services

Selection of categories: Dr. Kelvin Willoughby, February 2006.
Data Source: US Census Bureau, Economic Census, 1997 & 2002

Appendix 2

Benchmarking of BioBusiness Technology Industries in Minnesota

Comparison of NAICS Codes Employed in Phase 1 Analysis and Phase 2 Analysis

NAICS Code	NAICS Industry Category	Establishments with employees, 2002	Establishments without employees, 2002	Establishments with employees, 1997	Establishments without employees, 1997
3254	Pharmaceutical and medicine manufacturing	Phases 1 & 2	Phase 2	Phase 2	Phase 2
5417102	Research & development in the life sciences	Phases 1 & 2	Phase 2	Phase 2	Phase 2
3391	Medical equipment and supplies manufacturing	Phases 1 & 2	Phase 2	Phase 2	Phase 2
334510	Electromedical and electrotherapeutic apparatus manufacturing	Phase 2	Phase 2	Phase 2	Phase 2
334517	Irradiation apparatus manufacturing	Phase 2	Phase 2	Phase 2	Phase 2
6215	Medical and diagnostic laboratories	Phase 2	Phase 2	Phase 2	Phase 2
325193	Ethyl alcohol manufacturing	Phase 2	Phase 2	Phase 2	Phase 2
325221	Cellulose organic fiber manufacturing	Phase 2	Phase 2	Phase 2	Phase 2
311221	Wet corn milling	Phase 2	Phase 2	Phase 2	Phase 2
311222	Soybean processing	Phase 2	Phase 2	Phase 2	Phase 2
311223	Other oilseed processing	Phase 2	Phase 2	Phase 2	Phase 2
31212	Breweries	Phase 2	Phase 2	Phase 2	Phase 2
31213	Wineries	Phase 2	Phase 2	Phase 2	Phase 2
622	Hospitals	Phase 2	Phase 2	Phase 2	Phase 2
54194	Veterinary services	Phase 2	Phase 2	Phase 2	Phase 2

Yellow shading = data categories included in Phase 1 analysis.
Blue shading = data categories included only in the broadly defined version of biobusiness industries.

Dr. Kelvin Willoughby, February 2006.

Appendix 3

Explanation of the Data Sources Used in this Study

All of the results in this study (with the exception of those summarized in Table 3, Table 4 and Table 5 – to be explained further below) were drawn from calculations conducted by Dr. Kelvin Willoughby from data produced by the **U.S. Bureau of the Census** as part of its periodic **Economic Census** and also from the various **surveys of Non-employers** associated with the Economic Census. The Economic Census profiles American business every 5 years, from the national to the local level. The economic census is the major source of facts about the structure and functioning of the Nation's economy. It provides essential information for government, business, industry, and the general public. Title 13 of the United States Code (Sections 131, 191, and 224) directs the Census Bureau to take the economic census every 5 years, covering years ending in “2” and “7”.

The most recent available Economic Census results are for 1997 and 2002. The U.S. Census Bureau also conducts a number of monthly, quarterly, and annual surveys of businesses. These surveys, while providing more frequent observations, typically yield less kind-of-business and geographic detail than the economic census. They do not produce the kind of detailed information with the level of specificity that is needed for this study of statewide comparisons of biobusiness technology industries over time. This study has therefore been restricted to the data available from the 1997 and 2002 data sets.

The Economic Census data are divided in to two groups, establishments with paid employees (employers), and the much smaller businesses without paid employees (non-employers). The data for these two populations of organizations are collected separately. As explained in Appendix 2 of this report (above), this study required aggregating data from four separate census data sets: the 2002 employers data set, the 2002 non-employers data set, the 1997 employers data set, and the 1997 non-employers data set.

Industry Classifications Used in the Economic Census of Employers

Data from the 2002 Economic Census are published using primarily the 2002 North American Industry Classification System (NAICS). NAICS was first adopted in the United States, Canada, and Mexico in 1997. The 2002 Economic Census covers the following NAICS sectors:

Sector	*Description*
21	Mining
22	Utilities
23	Construction
31-33	Manufacturing
42	Wholesale Trade
44-45	Retail Trade
48-49	Transportation and Warehousing
51	Information
52	Finance and Insurance
53	Real Estate and Rental and Leasing
54	Professional, Scientific, and Technical Services

55 Management of Companies and Enterprises
56 Administrative and Support and Waste Management and Remediation Services
61 Educational Services
62 Health Care and Social Assistance
71 Arts, Entertainment, and Recreation
72 Accommodation and Food Services
81 Other Services (except Public Administration)

(Not listed above are the Agriculture, Forestry, Fishing, and Hunting sector (NAICS 11), partially covered by the census of agriculture conducted by the U.S. Department of Agriculture, and the Public Administration sector (NAICS 92), largely covered by the census of governments conducted by the Census Bureau.)

The 20 NAICS sectors are subdivided into 100 subsectors (three-digit codes), 317 industry groups (four-digit codes), and, as implemented in the United States, 1179 industries (six-digit codes). Prior to the 1997 Economic Census, data were published according to the Standard Industrial Classification (SIC) system. While many of the individual NAICS industries correspond directly to industries as defined under the SIC system, most of the higher level groupings do not.

Basis of Reporting Data Used in the Economic Census

The economic census is conducted on an establishment basis. A company operating at more than one location is required to file a separate report for each store, factory, shop, or other location. Each establishment is assigned a separate industry classification based on its primary activity and not that of its parent company.

Accurate and complete information on the physical location of each establishment is required to tabulate the census data for states, metropolitan and micropolitan areas, counties, and corporate municipalities (places) including cities, towns, townships, villages, and boroughs. Respondents were required to report their physical location (street address, municipality, county, and state) if it differed from their mailing address. For establishments not surveyed by mail (and those single-establishment companies that did not provide acceptable information on physical location), location information from administrative sources is used as a basis for coding.

Historical Background of the Economic Census

The economic census has been taken as an integrated program at 5-year intervals since 1967 and before that for 1954, 1958, and 1963. Prior to that time, individual components of the economic census were taken separately at varying intervals.

The economic census traces its beginnings to the 1810 Decennial Census, when questions on manufacturing were included with those for population. Coverage of economic activities was expanded for the 1840 Decennial Census and subsequent censuses to include mining and some commercial activities. The 1905 Manufactures Census was the first time a census was taken apart from the regular decennial population census. Censuses covering retail and wholesale trade and construction industries were added in 1930, as were some service trades in 1933. Censuses of construction, manufacturing, and the other business censuses were suspended during World War II.

The 1954 Economic Census was the first census to be fully integrated, providing comparable census data across economic sectors and using consistent time periods, concepts, definitions, classifications, and reporting units. It was the first census to be taken by mail, using lists of firms provided by the administrative records of other federal agencies. Since 1963, administrative records also have been used to provide basic statistics for very small firms, reducing or eliminating the need to send them census report forms.

The range of industries covered in the economic censuses expanded between 1967 and 2002. The census of construction industries began on a regular basis in 1967, and the scope of service industries, introduced in 1933, was broadened in 1967, 1977, and 1987. While a few transportation industries were covered as early as 1963, it was not until 1992 that the census broadened to include all of transportation, communications, and utilities. Also new for 1992 was coverage of financial, insurance, and real estate industries. With these additions, the economic census and the separate census of governments and census of agriculture collectively covered roughly 98 percent of all economic activity. New for 2002 is coverage of four industries classified in the Agriculture, Forestry, and Fishing sector under the SIC system: landscape architectural services, landscaping services, veterinary services, and pet care services.

Differences and Similarities of the 1997 and 2002 Economic Censuses

Both the 2002 Economic Census and the 1997 Economic Census present data based on the North American Industry Classification System (NAICS). Most industry classifications remained unchanged between 1997 and 2002, but NAICS 2002 includes substantial revisions within the Construction and Wholesale Trade sectors, and a number of revisions for the Retail and Information sectors.

For 2002, data for enterprise support establishments (those functioning primarily to support the activities of their company's operating establishments, such as a warehouse or a research and development laboratory) are included in the industry that reflects their activities. For 1997, such establishments were termed auxiliaries and were excluded from industry totals. The following industries included in 2002 were out of scope of the 1997 Economic Census: Landscape Architectural Services, Veterinary Services, Landscaping Services, and Pet Care (except Veterinary) Services.

Reliability of the Economic Census data

All data compiled in the economic census are subject to nonsampling errors. Nonsampling errors can be attributed to many sources: inability to identify all cases in the actual universe; definition and classification difficulties; differences in the interpretation of questions; errors in recording or coding the data obtained; and other errors of collection, response, coverage, processing, and estimation for missing or misreported data. Figures for the Construction sector are subject to sampling errors, since these data originate from a survey that included all large employers and a sample of the smaller ones.

The accuracy of these tabulated data is determined by the joint effects of the various nonsampling errors. No direct measurement of these effects has been obtained, except for estimation for missing or misreported data, included in later reports. Precautionary steps were taken in all phases of the collection, processing, and tabulation of the data in an effort to minimize the effects of nonsampling errors. In accordance with federal law governing census reports (Title 13 of the United States Code), no data are published that would disclose the operations of an individual establishment or business.

Purpose and Use of Nonemployer Statistics

Nonemployer Statistics provide U.S. and subnational economic data by industry for businesses that have no paid employees and are subject to federal income tax. Most types of businesses covered by the Census Bureau economic statistics programs are included in the Nonemployer Statistics. All of the Agriculture, Forestry, Fishing, and Hunting sector, except crop and animal production, are covered in Nonemployer Statistics. These industries typically are not covered in other Census Bureau economic programs. Most nonemployers are self-employed individuals operating very small unincorporated businesses, which may or may not be the owner's principal source of income. Although nonemployers constitute a large part of the business universe in terms of the number of establishments, they contribute a relatively small portion of the overall sales and receipts data. Tax-exempt businesses are excluded from the nonemployers tabulations.

Nonemployer Statistics have been released every 5 years since 1972, for years ending in "2" and "7" for selected industries in conjunction with Economic Census publications. The 2002 Nonemployer Statistics is part of the 2002 Economic Census Core Business Statistics Series. Nonemployer Statistics was first released as an annual series beginning with the 1998 report.

Nonemployer Statistics data originate chiefly from administrative records of the Internal Revenue Service (IRS). Data are primarily comprised of sole proprietorship businesses filing IRS Form 1040, Schedule C, although some of the data is derived from filers of partnership and corporation tax returns that report no paid employees. These data undergo complex processing, editing, and analytical review at the Census Bureau to distinguish nonemployers from employers, correct and complete data items, and form the final nonemployer universe.

Industry Classifications for the Non-employer Establishments

The Nonemployer Statistics are published based on the North American Industry Classification System (NAICS). The 1997 NAICS codes are the basis of industry classification for the nonemployer data tabulated for reference years 1997 through 2001. Starting with 2002, Nonemployer Statistics are classified and tabulated based on the 2002 NAICS codes, which contain several significant revisions from the 1997 codes.

The Nonemployer Statistics series includes the following NAICS sectors:

Sector	*Description*
11(pt)	Agricultural Support, Forestry, Fishing, and Hunting
21	Mining
22	Utilities
23	Construction
31-33	Manufacturing
42	Wholesale Trade
44-45	Retail Trade
48-49	Transportation and Warehousing
51	Information
52	Finance and Insurance
53	Real Estate and Rental and Leasing
54	Professional, Scientific, and Technical Services
56	Administrative and Support and Waste Management and Remediation Services
61	Educational Services

62 Health Care and Social Assistance
71 Arts, Entertainment, and Recreation
72 Accommodation and Foodservices
81 Other Services (except Public Administration)

The following NAICS industries are excluded from Nonemployer Statistics:
+ Crop Production (NAICS subsector 111)
+ Animal Production (NAICS subsector 112)
+ Investment Funds, Trusts, and Other Financial Vehicles (NAICS subsector 525)
+ Management of Companies and Enterprises (NAICS sector 55)

Sources for assigning Nonemployer Statistics industry classifications are the Social Security Administration, the Internal Revenue Service (IRS), and the Bureau of Labor Statistics. Industry classifications derived from the IRS are self-classified by tax filers.

The industry titles used in the non-employer series are the short NAICS titles. Nonemployer Statistics are limited to approximately 300 industries that are available through administrative-record sources, and are common to all three legal forms of organization applicable to nonemployer businesses. Because of this, data for nonemployers generally are provided at broader levels of industry detail than data for employers.

For those nonemployer businesses that are unclassified, NAICS classifications are imputed by assigning the code of a nonemployer business with comparable receipts located in the same county. Roughly four percent of the nonemployer universe tends to have imputed NAICS values.

Geography Classification of Non-employers

The Nonemployer Statistics data series provides summary tabulations for the United States, each state, the District of Columbia, each county (and county equivalent), and metropolitan areas.

Most geography codes are derived from the business owner`s mailing address identified from administrative records. Because the owner’s mailing address may not be the same as the physical location of the business, the resulting geography codes do not always represent where business is actually conducted.

The nonemployer tabulations exclude records with invalid, foreign, or military geographic locations. The independent cities in Virginia and the cities of Baltimore, MD, Carson City, NV, and St. Louis, MO, are treated as separate counties. Puerto Rico and Outlying Areas are not included in the nonemployer tabulations.

Legal Form of Organization Classification for Nonemployers

The legal form of organization for nonemployer businesses is derived from administrative record sources. Nonemployer Statistics presents U.S.-level data by the following three legal forms of organization:

+ Individual proprietorships (also referred to as “sole proprietorships”)
+ Partnerships
+ Corporations

Definition of “Establishments” (called “Enterprises” in this report)

Generally, an establishment is a single physical location where business is conducted or services or industrial operations are performed. However, for nonemployers we count each distinct business income tax return filed by a nonemployer business as an establishment. A nonemployer business may operate from its owner's home address or from a separate business location. Most geography codes are derived from the business owner`s mailing address, which may not be the same as the physical location of the business.

Definition of "Receipts" (called "Revenue" in this report)

Includes gross receipts, sales, commissions, and income received from trades and businesses, as reported on annual business income tax returns. Business income consists of all payments received for services rendered by nonemployer businesses, such as payments received as independent agents and contractors.

The composition of nonemployer receipts may differ from receipts data published for employer establishments. For example, for wholesale agents and brokers without payroll (nonemployers), the receipts item contains commissions received or earnings. In contrast, for wholesale agents and brokers with payroll (employers), the sales and receipts item published in the 2002 Economic Census represents the value of the goods involved in the transactions.

Non-employer Data Withheld from Publication

In accordance with U.S. Code, Title 13, Section 9, no data are published that would disclose the operations of an individual business. Because the preponderance of Nonemployer Statistics data items originate with the IRS, we adhere to both Census Bureau and IRS disclosure guidelines. For U.S.- and state-level data, we publish the number of establishments and receipts in a data cell only if it contains three or more nonemployer businesses. For county- and metropolitan area-level data, we publish the number of establishments and receipts in a data cell only if it contains ten or more nonemployer businesses. According to Census Bureau disclosure rules, when a small number of nonemployer businesses have a dominant share of receipts in a data cell, establishments and receipts are suppressed to protect the dominant businesses.

If more than 40 percent of either receipts or establishments in a published data cell are imputed, the Census Bureau suppresses both items because the data do not meet publication standards.

Post-2002 Data (from the Bureau of Labor Statistics)

The data used to produce the estimates and projections in Table 3, Table 4 and Table 5 (employment, enterprise and payroll figures for Minnesota only, for the period since 2002) were drawn from the Quarterly Census of Employment and Wages, of the U.S. Department of Labor's Bureau of Labor Statistics, and the Labor Market Information Office of the Minnesota Department of Employment and Economic Development (during March 2006). These data excluded all establishments without paid employees, and also contained many gaps due to the lower levels of precision and specificity of that data set compared with data from the five-yearly U.S. Economic Census. In addition, this data source does not cover revenue earned by enterprises (it covers only numbers of establishments, numbers of paid employees, and annual payroll).

Complete annual data for Minnesota from the Quarterly Census of Employment and Wages were available only for 2003 and 2004. Available data for 2005 covered the first quarter of 2005 only, and were also marred by considerable gaps and omissions in NAICS fields of importance to this study. Numbers for 2005 (Table 5) are therefore simply projections based on extrapolation of trends from 2003 to 2004.

In addition, the industry classifications used in the Quarterly Census of Employment and Wages do not drill down deeply enough to differentiate between NAICS Code 541710 (R&D in physical, engineering & biological sciences) and NAICS Code 5417102 (R&D in the life sciences). Analysis by this author of data from the 2002 U.S. Economic Census for Minnesota for these two categories revealed that total employment in NAICS Code 5417102 (R&D in the life sciences) in Minnesota is about 24% of the state's total employment in NAICS Code 541710 (R&D in physical, engineering & biological sciences). Calculations based on 2002 U.S. Economic Census were therefore used to estimate NAICS Code 5417102 employment in Minnesota for 2003-2005.

Because of various limitations in the available post-2002 data from the Quarterly Census of Employment and Wages, data from the 2002 U.S. Economic Census were used by this author to weight the more recent Bureau of Labor Statistics data and extrapolate from them to produce the estimates and projections for Minnesota from 2003 to 2005 that appear in Tables 3 to 5.

Using data from the Quarterly Census of Employment and Wages, produced by the U.S. Department of Labor's Bureau of Labor Statistics, can be very helpful for estimating certain biobusiness technology parameters for Minnesota for the years between the national Economic Censuses. However, given the primary purpose of this study (to compare the competitiveness of various U.S. states in biobusiness technology over time), it is much more appropriate to rely upon data from the U.S. Economic Census.

Note: The majority of the information in Appendix 3 was extracted from the web site of the U.S. Census Bureau and then edited for this report.
Internet address: http://www.census.gov/ Extracted: 02/16/06.

Appendix 4

Definitions of Selected NAICS Categories Employed in this Study

NAICS 3254 Pharmaceutical and medicine manufacturing

This industry comprises establishments primarily engaged in one or more of the following: (1) manufacturing biological and medicinal products; (2) processing (i.e., grading, grinding, and milling) botanical drugs and herbs; (3) isolating active medicinal principals from botanical drugs and herbs; and (4) manufacturing pharmaceutical products intended for internal and external consumption in such forms as ampoules, tablets, capsules, vials, ointments, powders, solutions, and suspensions.

NAICS 3391 Medical equipment and supplies manufacturing

This industry comprises establishments primarily engaged in manufacturing medical equipment and supplies. Examples of products made by these establishments are laboratory apparatus and furniture, surgical and medical instruments, surgical appliances and supplies, dental equipment and supplies, orthodontic goods, dentures, and orthodontic appliances.

NAICS 334510 Electromedical and electrotherapeutic apparatus manufacturing

This U.S. industry comprises establishments primarily engaged in manufacturing electromedical and electrotherapeutic apparatus, such as magnetic resonance imaging equipment, medical ultrasound equipment, pacemakers, hearing aids, electrocardiographs, and electromedical endoscopic equipment.

NAICS 334517 Irradiation apparatus manufacturing

This U.S. industry comprises establishments primarily engaged in manufacturing irradiation apparatus and tubes for applications, such as medical diagnostic, medical therapeutic, industrial, research and scientific evaluation. Irradiation can take the form of beta-rays, gamma-rays, X-rays, or other ionizing radiation.

NAICS 5417102 Research and Development in the Life Sciences

Establishments primarily engaged in conducting research and experimental development in medicine, health, biology, botany, biotechnology, agriculture, fisheries, forests, pharmacy, and other life sciences including veterinary sciences.

NAICS 6215 Medical and diagnostic laboratories

This industry comprises establishments known as medical and diagnostic laboratories primarily engaged in providing analytic or diagnostic services, including body fluid analysis and diagnostic imaging, generally to the medical profession or to the patient on referral from a health practitioner.

NAICS 325193 Ethyl alcohol manufacturing

This U.S. industry comprises establishments primarily engaged in manufacturing nonpotable ethyl alcohol.

NAICS 325221 Cellulosic organic fiber manufacturing

This U.S. industry comprises establishments primarily engaged in (1) manufacturing cellulosic (i.e., rayon and acetate) fibers and filaments in the form of monofilament, filament yarn, staple, or tow or (2) manufacturing and texturizing cellulosic fibers and filaments.

NAICS 311221 Wet corn milling

This U.S. industry comprises establishments primarily engaged in wet milling corn and other vegetables (except to make ethyl alcohol). Examples of products made in these establishments are corn sweeteners, such as glucose, dextrose, and fructose; corn oil; and starches (except laundry).

NAICS 311222 Soybean processing

This U.S. industry comprises establishments engaged in crushing soybeans. Examples of products produced in these establishments are soybean oil, soybean cake and meal, and soybean protein isolates and concentrates.

NAICS 311223 Other oilseed processing

This U.S. industry comprises establishments engaged in crushing oilseeds (except soybeans) and tree nuts, such as cottonseeds, linseeds, peanuts, and sunflower seeds.

NAICS 31212 Breweries

This industry comprises establishments primarily engaged in brewing beer, ale, malt liquors, and nonalcoholic beer.

NAICS 31213 Wineries

This industry comprises establishments primarily engaged in one or more of the following: (1) growing grapes and manufacturing wine and brandies; (2) manufacturing wine and brandies from grapes and other fruits grown elsewhere; and (3) blending wines and brandies.

NAICS 622 Hospitals

Industries in the Hospitals subsector provide medical, diagnostic, and treatment services that include physician, nursing, and other health services to inpatients and the specialized accommodation services required by inpatients. Hospitals may also provide outpatient services as a secondary activity. Establishments in the Hospitals subsector provide inpatient health services, many of which can only be provided using the specialized facilities and equipment that form a significant and integral part of the production process.

NAICS 54194 Veterinary Services

This industry comprises establishments of licensed veterinary practitioners primarily engaged in the practice of veterinary medicine, dentistry, or surgery for animals; and establishments primarily engaged in providing testing services for licensed veterinary practitioners.

Note: All of the above definitions were extracted from the web site of the U.S. Census Bureau. Internet address: http://www.census.gov/ Extracted: 02/16/06.

Appendix 5

Biobusiness Technology Industries, 1997-2002
Minnesota and the United States

	Establishments	Receipts ($1,000)	Annual payroll ($1,000)	Paid employees
United States, 2002				
Medical devices	17,081	$82,587,327	$17,295,804	397,968
Pharmaceuticals	2,798	$140,607,373	$13,788,405	248,947
R&D in the life sciences	6,119	$26,316,797	$17,418,708	244,737
Agri-bio & bio-industrial technology	1,872	$52,187,349	$3,524,647	75,713
Biobusiness clinical services	44,110	$517,329,365	$202,744,232	5,412,993
Biobusiness technology (narrowly defined	55,410	$331,057,782	$60,994,730	1,170,626
Biobusiness (broadly defined)	99,520	$848,387,147	$263,738,962	6,583,619
Minnesota, 2002				
Medical devices	439	$4,771,758	$1,077,962	21,966
Pharmaceuticals	58	$1,020,849	$100,084	1,928
R&D in the life sciences	121	$245,711	$97,658	1,752
Agri-bio & bio-industrial technology	25	$341,676	$14,512	1,056
Biobusiness clinical services	812	$9,061,865	$3,808,966	103,626
Biobusiness technology (narrowly defined	903	$6,613,261	$1,371,421	28,267
Biobusiness (broadly defined)	1,715	$15,675,126	$5,180,387	131,893
United States, 1997				
Medical devices	15,603	$60,427,924	$13,290,733	362,411
Pharmaceuticals	2,242	$92,971,074	$10,111,751	203,818
R&D in the life sciences	4,044	$11,722,721	$4,681,077	98,279
Agri-bio & bio-industrial technology	1,466	$51,453,884	$3,252,271	77,823
Biobusiness clinical services	17,319	$379,575,057	$155,795,777	4,943,672
Biobusiness technology (narrowly defined	45,529	$233,535,489	$36,737,581	906,767
Biobusiness (broadly defined)	62,848	$613,110,546	$192,533,358	5,850,439
Minnesota, 1997				
Medical devices	426	$3,718,124	$911,090	23,380
Pharmaceuticals	42	$712,764	$75,318	1,892
R&D in the life sciences	87	$144,731	$46,505	1,154
Agri-bio & bio-industrial technology	60	$2,303,126	$90,361	3,536
Biobusiness clinical services	341	$5,821,008	$2,509,113	84,208
Biobusiness technology (narrowly defined	814	$6,996,206	$1,174,814	31,094
Biobusiness (broadly defined)	1,155	$12,817,214	$3,683,927	115,302

Appendix 6

Biobusiness Technology Industries
Minnesota's Share of the US Total, 1997-2002

	Establishments	Receipts ($1,000)	Annual payroll ($1,000)	Paid employees
Minnesota's Share of US Total, 2002				
Medical devices	2.57%	5.78%	6.23%	5.52%
Pharmaceuticals	2.07%	0.73%	0.73%	0.77%
R&D in the life sciences	1.98%	0.93%	0.56%	0.72%
Agri-bio & bio-industrial technology	1.34%	0.65%	0.41%	1.39%
Biobusiness clinical services	1.84%	1.75%	1.88%	1.91%
Biobusiness technology (narrowly defined	1.63%	2.00%	2.25%	2.41%
Biobusiness (broadly defined)	1.72%	1.85%	1.96%	2.00%
Minnesota's Share of US Total, 1997				
Medical devices	2.73%	6.15%	6.86%	6.45%
Pharmaceuticals	1.87%	0.77%	0.74%	0.93%
R&D in the life sciences	2.15%	1.23%	0.99%	1.17%
Agri-bio & bio-industrial technology	4.09%	4.48%	2.78%	4.54%
Biobusiness clinical services	1.97%	1.53%	1.61%	1.70%
Biobusiness technology (narrowly defined	1.79%	3.00%	3.20%	3.43%
Biobusiness (broadly defined)	1.84%	2.09%	1.91%	1.97%
Increase or Decrease in Minnesota's Share of the US Total, 1997-2002				
Medical devices	-0.16%	-0.38%	-0.62%	-0.93%
Pharmaceuticals	0.20%	-0.04%	-0.02%	-0.15%
R&D in the life sciences	-0.17%	-0.30%	-0.43%	-0.46%
Agri-bio & bio-industrial technology	-2.76%	-3.82%	-2.37%	-3.15%
Biobusiness clinical services	-0.13%	0.22%	0.27%	0.21%
Biobusiness technology (narrowly defined	-0.16%	-1.00%	-0.95%	-1.01%
Biobusiness (broadly defined)	-0.11%	-0.24%	0.05%	0.03%
Percentage Change in Minnesota's Share of the US Total, 1997-2002				
Medical devices	-5.9%	-6.1%	-9.1%	-14.4%
Pharmaceuticals	10.7%	-5.3%	-2.6%	-16.6%
R&D in the life sciences	-8.1%	-24.4%	-43.6%	-39.0%
Agri-bio & bio-industrial technology	-67.4%	-85.4%	-85.2%	-69.3%
Biobusiness clinical services	-6.5%	14.2%	16.7%	12.4%
Biobusiness technology (narrowly defined	-8.8%	-33.3%	-29.7%	-29.6%
Biobusiness (broadly defined)	-6.2%	-11.6%	2.7%	1.7%

Appendix 7

All Enterprises, All Industries, 1997-2002 (US & Selected States, Employers and Non-employers)

Ratio of 2002 Level Over 1997 Level

	Number of establishments	Receipts (revenue)	Annual payroll	Number of employees
United States	1.12	1.20	1.28	1.08
Minnesota	1.10	1.13	1.32	1.09
California	1.15	1.16	1.35	1.13
Iowa	1.06	1.05	1.25	1.06
Massachusetts	1.06	1.12	1.36	1.09
New Jersey	1.10	1.13	1.25	1.09
New York	1.15	1.07	1.30	1.08
North Carolina	1.15	1.07	1.26	1.04
Ohio	1.07	1.05	1.17	1.01
Utah	1.16	1.12	1.34	1.14
Washington	1.07	1.11	1.33	1.07
Wisconsin	1.09	1.13	1.23	1.04

Ratio of 2002 Share Over 1997 Share

	Establishments	Receipts (revenue)	Annual payroll	Number of employees
United States	0.00%	0.00%	0.00%	0.00%
Minnesota	-0.04%	-0.11%	0.07%	0.02%
California	0.27%	-0.39%	0.63%	0.52%
Iowa	-0.06%	-0.12%	-0.02%	-0.02%
Massachusetts	-0.14%	-0.15%	0.18%	0.04%
New Jersey	-0.05%	-0.21%	-0.08%	0.04%
New York	0.17%	-0.67%	0.12%	0.05%
North Carolina	0.07%	-0.29%	-0.05%	-0.09%
Ohio	-0.19%	-0.49%	-0.36%	-0.26%
Utah	0.02%	-0.04%	0.03%	0.05%
Washington	-0.10%	-0.13%	0.07%	-0.02%
Wisconsin	-0.05%	-0.11%	-0.08%	-0.08%

Percentage Change in Share of US Total, 1997-2002

	Establishments	Receipts	Annual payroll	Paid employees
United States	0.00%	0.00%	0.00%	0.00%
Minnesota	-1.88%	-6.14%	3.26%	0.93%
California	2.19%	-3.68%	5.21%	4.72%
Iowa	-5.63%	-12.33%	-2.61%	-1.63%
Massachusetts	-5.43%	-6.81%	6.06%	1.56%
New Jersey	-1.64%	-6.43%	-2.17%	1.38%
New York	2.41%	-11.38%	1.46%	0.71%
North Carolina	2.38%	-11.38%	-1.82%	-3.18%
Ohio	-4.92%	-12.77%	-8.34%	-5.79%
Utah	3.09%	-7.15%	4.55%	6.08%
Washington	-4.82%	-7.38%	3.54%	-0.79%
Wisconsin	-2.84%	-6.27%	-3.85%	-3.54%

All industries (raw figures)

2002	Establishments	Receipts ($1,000)	Annual payroll ($1,000)	Paid employees
United States	24,537,444	$22,132,046,054	$3,727,706,910	108,991,968
Minnesota	471,568	$371,096,640	$80,064,569	2,298,915
California	3,048,328	$2,232,494,692	$476,989,302	12,598,723
Iowa	252,878	$181,099,380	$33,936,126	1,203,294
Massachusetts	591,832	$458,863,187	$116,445,171	2,884,548
New Jersey	742,000	$676,970,280	$139,519,565	3,509,094
New York	1,783,625	$1,150,018,870	$318,072,895	7,178,673
North Carolina	688,772	$501,199,106	$96,633,784	3,146,016
Ohio	883,163	$745,853,161	$149,520,592	4,630,149
Utah	201,753	$120,210,257	$24,531,327	865,672
Washington	493,800	$356,870,619	$80,192,537	2,123,861
Wisconsin	418,769	$355,012,567	$72,111,040	2,293,722

All industries (percentage of US Total)

2002	Establishments	Receipts	Annual payroll	Paid employees
United States	100.00%	100.00%	100.00%	100.00%
Minnesota	1.92%	1.68%	2.15%	2.11%
California	12.42%	10.09%	12.80%	11.56%
Iowa	1.03%	0.82%	0.91%	1.10%
Massachusetts	2.41%	2.07%	3.12%	2.65%
New Jersey	3.02%	3.06%	3.74%	3.22%
New York	7.27%	5.20%	8.53%	6.59%
North Carolina	2.81%	2.26%	2.59%	2.89%
Ohio	3.60%	3.37%	4.01%	4.25%
Utah	0.82%	0.54%	0.66%	0.79%
Washington	2.01%	1.61%	2.15%	1.95%
Wisconsin	1.71%	1.60%	1.93%	2.10%

All industries (raw figures)

1997	Establishments	Receipts ($1,000)	Annual payroll ($1,000)	Paid employees
United States	21,856,644	$18,394,792,801	$2,909,672,217	101,372,992
Minnesota	428,077	$328,597,781	$60,521,362	2,118,563
California	2,657,197	$1,926,436,924	$353,886,124	11,189,977
Iowa	238,682	$171,683,802	$27,197,806	1,137,677
Massachusetts	557,465	$409,248,158	$85,694,294	2,641,663
New Jersey	671,987	$601,289,536	$111,323,493	3,219,285
New York	1,551,340	$1,078,545,164	$244,693,091	6,629,476
North Carolina	599,261	$470,034,921	$76,828,141	3,022,304
Ohio	827,409	$710,618,980	$127,326,110	4,571,387
Utah	174,329	$107,604,107	$18,314,435	759,011
Washington	462,138	$320,244,820	$60,454,020	1,991,185
Wisconsin	383,921	$314,815,244	$58,541,699	2,211,774

All industries (percentage of US Total)

1997	Establishments	Receipts	Annual payroll	Paid employees
United States	100.00%	100.00%	100.00%	100.00%
Minnesota	1.96%	1.79%	2.08%	2.09%
California	12.16%	10.47%	12.16%	11.04%
Iowa	1.09%	0.93%	0.93%	1.12%
Massachusetts	2.55%	2.22%	2.95%	2.61%
New Jersey	3.07%	3.27%	3.83%	3.18%
New York	7.10%	5.86%	8.41%	6.54%
North Carolina	2.74%	2.56%	2.64%	2.98%
Ohio	3.79%	3.86%	4.38%	4.51%
Utah	0.80%	0.58%	0.63%	0.75%
Washington	2.11%	1.74%	2.08%	1.96%
Wisconsin	1.76%	1.71%	2.01%	2.18%

Appendix 8

Comments on the Interpretation of Industry Density Indices

As explained in the main body of this report, an industry density index may be used as an indicator of the relative capacity of regions to generate particular kinds of industries. It may help you to tell whether or not the level of development of an industry in a particular region is simply a function of the overall economy of that region, within the wider economy, or whether it is a function of some special quality of that region that is especially influential on that particular industry. Each index tells you something about the regional strength of an industry, standardizing the figures to take into account differences in the scale of the economies in the regions (e.g., states, counties or cities) under consideration, the state of the industry in the larger region (e.g., nation, as the case may be), and the current state of the whole economy throughout the nation (or whatever reference region is used).

The generic formula for calculating an industry density index (IDI) for *industry X* in *region N*, using *factor F* as a source of data within a wider reference region (*region R*) is as follows:

Industry$_x$ IDI$_f$ for region$_n$ = {(factor$_f$ for industry$_x$ in region$_n$)/(factor$_f$ for industry$_x$ in region$_r$)}/{(factor$_f$ for all industries in region$_n$)/(factor$_f$ for all industries in region$_r$)}

As can be seen from this formula, changes in industry density indices over time tell you whether or not changes in the level of an industry in a region follow changes in the overall economy over time, or whether they are driven by some other more peculiar factors.

Thus, a simple increase in the level of employment for industry$_x$ in city$_n$ tells you nothing other than the fact that employment in that industry has changed in that city. This provides no information about the significance of that change. A change in relative percentages, however, reveals more useful information. Thus an increase in the percentage of nationwide employment in industry$_x$ accounted for by employment for industry$_x$ in city$_n$ tells you that the relative position of city$_n$ in industry$_x$ in that country has increased. While simple percentages are perhaps much easier to grasp than density indices, they nevertheless do not tell you whether or not city$_n$ has actually improved as a place for employment in industry$_x$ compared with other places, or whether the increases are simply due to increases in the aggregate size of that city's economy.

In contrast, an increase in the employment density index for industry$_x$ in city$_n$ tells you that city$_n$ has become stronger for employment in industry$_x$—completely apart from whether or not its overall economy has lost or gained ground *vis-à-vis* other cities. Thus, even though industry density indices may be slightly less intuitive for many observers, compared with raw numbers or compared with percentages, they may actually be utilized as practical tools to help evaluate whether or not industry policies in a city or region (such as a state) are effective, compared with the policies employed in other cities or regions. They can also be used to evaluate the relative prowess of entrepreneurs and industry leaders in particular industries across regions.

For example, in Figure 5 of this report we can see that from 1997 to 2002 total employment in the medical devices industry in California grew from just over 60,000 people to just over 79,000 people; and we know, from Figure 7, that this growth represented an increase from 16.6% to 19.9% of nationwide employment in the medical devices industry. If we only had these numbers available to us we might be tempted to explain this away as resulting simply from a growth in the overall size of California's economy during that period. As the numbers in Appendix 7 reveal, however, California's share of the overall national economy increased only marginally during that period, from 11.04% (11.1 million) of total nationwide employment to 11.56% (12.6 million) of total nationwide employment. These numbers reveal that California both enjoyed a relatively stronger position than other states in medical devices employment and that it improved its relative position in that industry at a significantly greater rate than it's whole economy grew. This total picture of medical devices employment in California is summarized very succinctly in Figure 9: California's employment density index for medical devices increased from 1.51 to 1.72 during the five years to 2002. The fact that California commenced that period with an employment density index of 1.51 means that it was already more than 150% stronger than the norm for the United States before the recent increases occurred. In short, California got better at generating medical devices jobs, compared with the rest of the country, during the period in question.

Minnesota's case is also instructive. For example, we can see from Figure 5 that from 1997 to 2002 total employment in the medical devices industry in Minnesota (as defined in this report – see Appendix 1 for the pertinent NAICS codes) declined from about 23,400 people to about 22,000 people; and we know, from Figure 7, that this decline represented a drop from 6.5% to 5.5% of nationwide employment in the medical devices industry. If we only had these numbers available to us we might be tempted to explain this away as resulting simply from a reduction in the overall size of Minnesota's economy during that period, or at least a reduction in its share of the national economy, rather than from anything related to the medical devices industry itself. As the numbers in Appendix 7 reveal, however, Minnesota's share of the overall national economy actually increased marginally during that period, from 2.09% (2.1 million) of total nationwide employment to 2.11% (2.3 million) of total nationwide employment – this was not much, but it was an increase, not a decrease. Indeed, from 1997 to 2002 Minnesota increased the total size of its economy, no matter which way it was measured. The crude increases, as revealed in Appendix 7, were as follows: employment (paid employees) = 9% increase; enterprises = 10% increase; revenue (receipts) = 13% increase; payroll = 32% increase. It looks like Minnesotan employees (all fields aggregated, not adjusting for inflation) became wealthier over that 5-year period, and did so at a slightly faster rate than employees across the whole nation (the national increase was 28%). These figures together reveal that the weakening position of Minnesota's overall medical devices industry from 1997 to 2002 could not be accounted for by a weakening of the overall Minnesota economy. Rather, the employment dynamics of the medical devices industry during that period appeared to be somewhat independent of the employment dynamics of the whole economy.

These circumstances for medical devices employment in Minnesota are also summarized very succinctly in Figure 9: As noted earlier in this report, Minnesota's employment density index for medical devices decreased from 3.09 to 2.62 during the five years to 2002. In short, the indications from the simple numbers in Figures 3 and 5 that Minnesota lost some ground compared with other U.S. states in generating medical devices jobs during that period are confirmed by the industry density indices as being driven by forces other than aggregate economic forces. Industry density indices provide a very simple and robust way of isolating industry-specific performance from overall regional economic forces. An industry density index (as mapped in Figure 9) provides an easy way of combining the information from Figure 5, Figure 7 and Appendix 7 in to one simple indicator.

Appendix 9

Comparison of Approaches Followed by Willoughby and Battelle / SSTI in the Use of U.S. Federal Data Sources as Proxies for Biobusiness Technology Industries

On April 10, 2006 (after the research and analysis for this report was completed) the following report, which was prepared for BIO – The Biotechnology Industry Organization – was released to the public: Battelle Technology Partnership Practice and SSTI, *Growing the Nation's Bioscience Sector: State Bioscience Initiatives 2006* (Battelle Memorial Institute, April 2006). That report also used data provided by the U.S. Federal Government as the basis for its calculations of state performance levels in the biobusiness technology industries (labeled by Battelle / SSTI as the "bioscience" industries). In addition, the data in that report were also organized using NAICS categories. However, there are some differences in the way that data and NAICS categories have been employed in the two studies (the Willoughby study and the Battelle / SSTI study).

Data Sources

The primary data source for the Willoughby study was the Economic Census conducted by the U.S. Bureau of the Census together with data from the various surveys of non-employers associated with the Economic Census. The primary data source for the Battelle / SSTI study was the Quarterly Census of Employment and Wages (QCEW) of the U.S. Department of Labor's Bureau of Labor Statistics.

The primary disadvantage of the Economic Census data is that they are collected only every five years. The primary advantages of the Census data, however, are that they are more comprehensive and rigorous than the QCEW data, and that they drill down deeper in to finer sub-categories of the NAICS categories than the QCEW data. The primary advantage of the QCEW data is that they are collected every quarter, rather than every five years. The primary disadvantages of the QCEW data are that: they are less comprehensive and rigorous than the Census data; they are not disaggregated in to the same level of fine sub-categories as are the Census data; and they exclude information about revenue accrued by each establishment.

In addition to these basic differences generated by the choice of data sources, the two studies have one other difference. The Battelle / SSTI study includes information only from enterprises that have employees on the payroll. The Willoughby study includes information from both from enterprises that have employees on the payroll and enterprises without employees (e.g., small firms in which the owners / entrepreneurs work without being placed on the payroll). About 39% of all biobusiness technology enterprises in the United States (in 2002) were non-employer establishments.

Selection of NAICS Categories

As revealed by the following table, the two studies have employed different selections of NAICS industry categories to act as proxies for the bioscience / biobusiness-technology industries. The NAICS categories included by Battelle / SSTI in their study, but rejected by the Willoughby study, account for just over 25% of the total national "bioscience" industry employment for the U.S. (according the 2002 U.S. Economic Census data).

Comparison of NAICS Codes Employed in the Willoughby Study and the Battelle / SSTI Study

NAICS Code	NAICS Industry Category	Classified by Battelle / SSTI as "bioscience"	Classified by Willoughby as "biobusiness technology"	Employees, US total, 2002 Economic Census (excluding non-employers)	Percentage of Willoughby's Total	Percentage of Battelle / SSTI's total	Comments by Willoughby
5417101	Research & development in the physical and engineering sciences	yes	no	312,680		17.2%	Subcategory of NAICS 541710 - Research & development in the physical, engineering & life sciences
5417102	Research & development in the life sciences	yes	yes	489,474	34.6%	26.9%	Subcategory of NAICS 541710 - Research & development in the physical, engineering & life sciences
32541	Pharmaceutical and medicine manufacturing	yes	yes	248,947	17.6%	13.7%	Battelle / SSTI and Willoughby are in complete agreement about including all of these NAICS categories as part of "bioscience" / "biobusiness technology."
33911	Medical equipment and supplies manufacturing	yes	yes	326,490	23.1%	18.0%	
62151	Medical and diagnostic laboratories	yes	yes	203,261	14.4%	11.2%	
311221	Wet corn milling	yes	yes	9,546	0.7%	0.5%	
311222	Soybean processing	yes	yes	7,318	0.5%	0.4%	
311223	Other oilseed processing	yes	yes	1,533	0.1%	0.1%	
325193	Ethyl alcohol manufacturing	yes	yes	2,265	0.2%	0.1%	
325221	Cellulose organic fiber manufacturing	yes	yes	1,819	0.1%	0.1%	
334510	Electromedical and electrotherapeutic apparatus manufacturing	yes	yes	58,105	4.1%	3.2%	
334517	Irradiation apparatus manufacturing	yes	yes	13,373	0.9%	0.7%	
31212	Breweries	no	yes	28,347	2.0%		Both breweries and wineries use fermentation technology as a pivotal part of their manufacturing activities; these industries use biological technology as an integral dimension of their production systems.
31213	Wineries	no	yes	24,885	1.8%		
325199	All other basic organic chemical mfg.	yes	no	77,995		4.3%	These five sub-categories of "NAICS 3253 - Pesticide, fertilizer and other agricultural chemical manufacturing" do not, on the whole, employ biological technology as part of their manufacturing systems. If these industries are included as part of "biobusiness technology" or "bioscience" just because their products are applied in agriculture, then we would also logically also need to include all other products used in agriculture, such as harvesting equipment, irrigation equipment, greenhouse control systems, dairy machinery, etc. (which Battelle / SSTI has not done).
325311	Nitrogenous fertilizer manufacturing	yes	no	4,760		0.3%	
325312	Phosphatic fertilizer manufacturing	yes	no	6,306		0.3%	
325314	Fertilizer, mixing only, manufacturing	yes	no	9,687		0.5%	
325320	Pesticide and other ag. chemical mfg.	yes	no	10,562		0.6%	
334516	Analytical laboratory instrument manufacturing	yes	no	34,024		1.9%	The products of this industry are mostly not specialized towards application in the life sciences.

Dr. Kelvin Willoughby, April 2006.

Appendix 10

Report from Phase One of this Study