



## Minnesota's Competitive Position in the Biobusiness Technology Industries

Dr. Kelvin Willoughby  
President  
Willoughby International LLC

February 2011



**the BioBusiness Alliance  
of Minnesota™**

# **Biobusiness 2010:**

## **Minnesota's Competitive Position in the Biobusiness Technology Industries**

A Report of Research and Analysis Conducted for the

*BioBusiness Alliance of Minnesota*

Dr. Kelvin W. Willoughby  
President  
*Willoughby International LLC*

13 January 2011

*BioBusiness Alliance of Minnesota*  
1550 Utica Avenue South, Suite 725  
Saint Louis Park, MN 55416

# *Biobusiness 2010:*

## *Minnesota's Competitive Position in the Biobusiness Technology Industries*

### *Table of Contents*

#### *Table of Contents*

#### **Executive Summary**

- 1. Introduction**
- 2. Basic Profile of Minnesota's Biobusiness Economy**
- 3. Overview of Methodology and Data Sources**
- 4. Biobusiness Technology**
- 5. Medical Devices**
- 6. R&D in the Life Sciences**
- 7. Agri-bio and Bio-industrial Technology**
- 8. Pharmaceuticals**
- 9. Summary and Conclusions**

#### **Appendices**

- 1 Definitions of Basic BioBusiness Concepts
- 2 Definitions of Selected NAICS Categories Employed in this Study
- 3 Data Sources and Changes in the NAICS Classification System Since 2002
- 4 Explanation and Definition of Industry Density Indices
- 5 Bio Production and Processing Industries

#### **List of Figures**

# *Biobusiness 2010:*

## *Minnesota's Competitive Position in the Biobusiness Technology Industries*

*Report of the 2010 Statewide Assessment Project  
for the BioBusiness Alliance of Minnesota*

### *Executive Summary*

By late 2007, the most recent year for which national data from the U.S. Economic Census is available, the biobusiness technology sector in the United States consisted of over 36,500 establishments, almost 1.2 million paid employees, an aggregate annual payroll of over \$74 billion, and aggregate annual revenues of over \$450 billion. The biobusiness technology sector in the U.S. is substantial, dynamic and internationally prominent. In addition, the average annual wage in the bioscience technology sector, across all employment categories—at \$64,116—was about 55% greater than the average private sector wage.<sup>1</sup> Biobusiness technology is an important field of industry from the point of view of economic development across the nation; and it is a field in which many American states, and many regions and countries elsewhere in the world, are competing to gain a share of the high-value employment opportunities and revenue-generation advantages that it represents.

This report summarizes the results of the second statewide biobusiness assessment conducted for the BioBusiness Alliance of Minnesota. The results of the first assessment, conducted in 2005 and early 2006, was published in August 2006.<sup>2</sup> The primary goals of the 2010 statewide biobusiness assessment project were similar to those of the 2006 project: to provide a baseline assessment of biobusiness technology in Minnesota against

---

<sup>1</sup> These numbers cited here were calculated by Dr. Kelvin Willoughby using data from the 2007 U.S. Economic Census of the U.S. Bureau of the Census. The data exclude employment inside universities, hospitals and other not-for-profit organizations involved in biobusiness.

<sup>2</sup> For the full report and executive summary of the original statewide assessment project, see, *Biobusiness: Minnesota's Present Position and Future Prospects*, Report of the Statewide Biobusiness Assessment Project of the BioBusiness Alliance of Minnesota (St. Louis Park: BioBusiness Alliance of Minnesota, August 2006). That project was co-chaired under the auspices of the BioBusiness Alliance of Minnesota by Vincent Ruane and Kelvin Willoughby (Dale Wahlstrom, Chairman of the Board; Jeremy Lenz, Project Executive). The principle author of the 2006 report (which may be downloaded from the website of the BioBusiness Alliance, at [www.biobusinessalliance.org](http://www.biobusinessalliance.org)) was Kelvin Willoughby.

which the state may be benchmarked; and, to provide thoughtful, well-researched recommendations to help guide the state in becoming more competitive in specific areas of biobusiness. An additional goal of the 2010 project was to document and analyze changes that have taken place in Minnesota's biobusiness technology industries—specifically, increases or decreases in key economic variables in the constituent industries, in comparison with changes in equivalent industries in the selected competitor states and in the nation as a whole—during the time that has passed since the date of the previous U.S. Economic Census in 2002.

*Biobusiness is economic activity devoted to the development or commercialization of bioscience or bioscience-related technologies, products or services.* In other words, biobusiness is technology-based economic activity that utilizes or is informed by biology. Biobusiness deals with the spectrum of enterprises from start-ups to established firms, together with associated infrastructure and support services (such as those provided by legal service firms, management consultants, marketing organizations, accountants, lobbyists, investors, regulatory affairs specialists, or specialized property developers). The focus of this assessment project, however, was on a narrower set of enterprises: those whose primary business is the development or commercialization of what may be labeled as “biobusiness technology.” *Biobusiness technology is technology devoted to the biological domain, as either a system of tools or as a field of application.* Put simply, biobusiness technology is technology focused on biology. It is the technological foundation of biobusiness.

The primary data source that has been drawn upon in this report for analysis of Minnesota's competitive position is the periodic Economic Census conducted by the U.S. Census Bureau, 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”), which was implemented for the first time in 1997. The most recent Economic Census data were generated at the close of 2007 and were released during 2010. Thus, the most recent census data available at the time of writing this report are 2007 data. This report also draws upon data from the two previous Economic Censuses, from 1997 and 2002, thus allowing us to conduct analysis over a period of ten years.

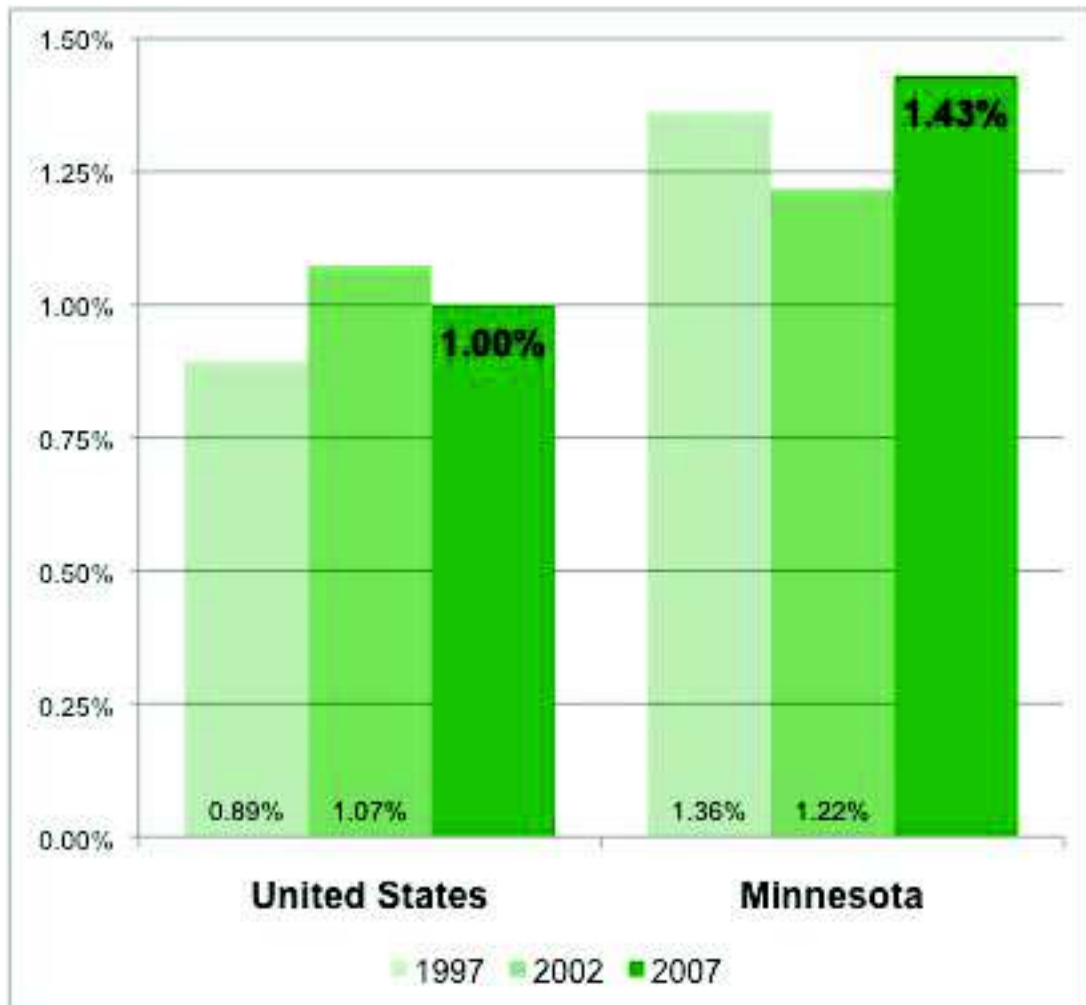
In this project a carefully selected set of NAICS codes was employed to act as a proxy for the overall biobusiness technology sector. The aggregated (i.e., “macro”) set of industries represented by those codes was labeled the “biobusiness technology industry,” and comprised five constituent industry segments, themselves also corresponding to a carefully selected set of NAICS codes: the medical devices industry, the R&D in the life sciences industry, the agri-bio and bio-industrial technology industries, the pharmaceuticals industry and the medical and diagnostic laboratories industry. Data for all five segments were included in the analysis; and detailed analysis was conducted for the first four of those segments.

### **Basic Findings and Overview of the Biobusiness Technology Industry**

As shown in Figure 1, Minnesota's economy is more heavily oriented towards biobusiness technology employment than is the economy of the whole country. In fact, biobusiness technology employment in 2007, as a proportion of employment in all

industries, was 43% greater in Minnesota than in the nation as a whole. While the numbers have fluctuated over time, Minnesota remained consistently above the national norm throughout the previous decade. This means that Minnesota's future employment prospects are more dependent than most other states on what happens to its biobusiness sector. In short, more is at stake for Minnesota in biobusiness than is the case for most other states.

**Executive Summary: Figure 1**

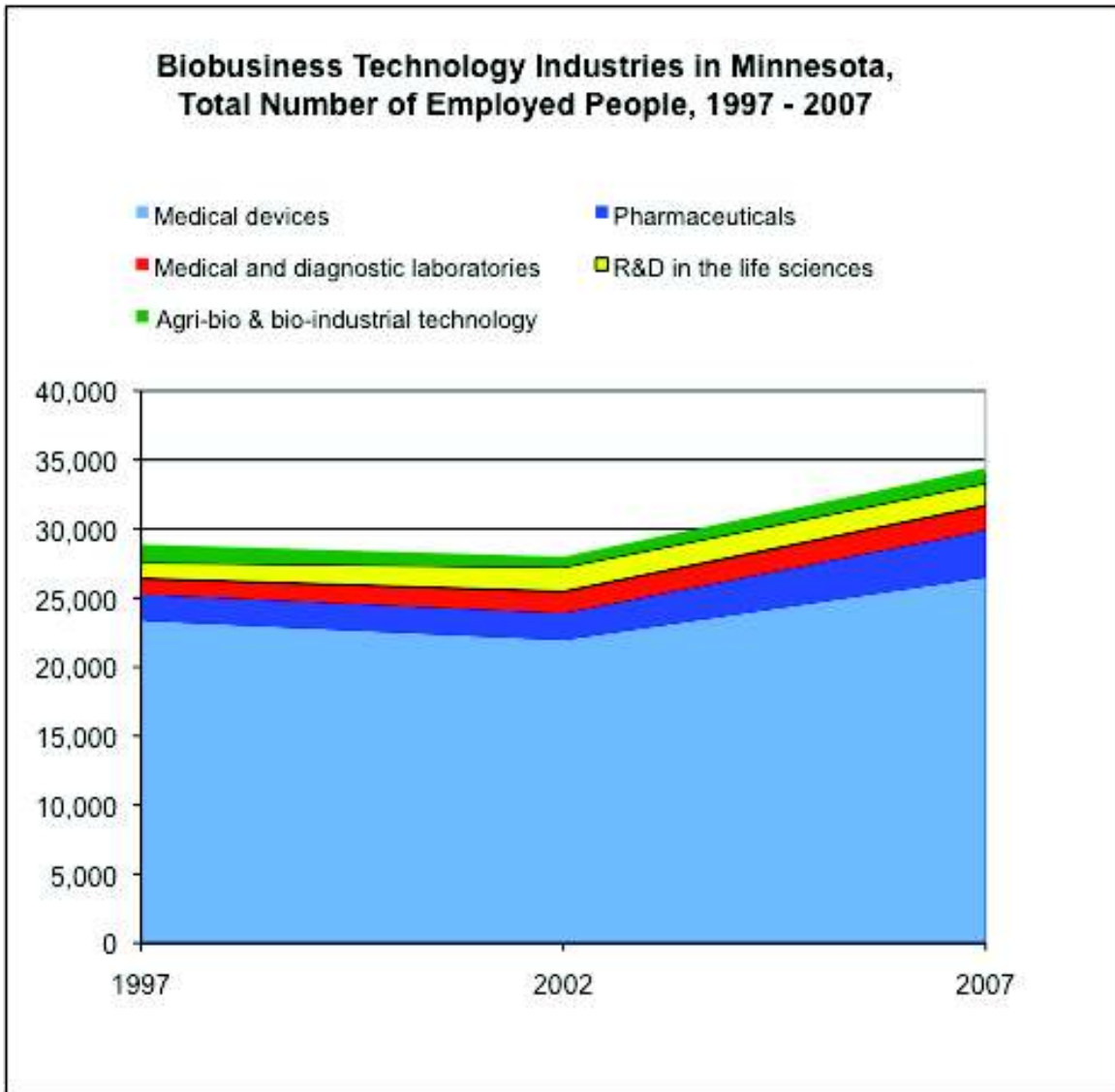


Minnesota's biobusiness sector is also distinctive, due in large part to the extraordinary role played by the medical devices industry in the mix of biobusiness technology industries in the state. The percentage of biobusiness technology employment accounted for by the medical devices segment (77%) is more than twice as large in Minnesota than it is in the nation as a whole; and the ratio of Minnesota to the nation (in the percentage of biobusiness technology employment accounted for by the medical devices segment) increased from 202% to 231% during the decade leading to the most



recent Economic Census. Thus, medical devices not only play a dominant role in the state's biobusiness technology industry but the prominence of that role has been growing.

**Executive Summary: Figure 2**



What about the absolute size of Minnesota's biobusiness technology sector? By late 2007 the state was home to almost 34,500 biobusiness technology employees. Additionally, total biobusiness technology employment in Minnesota grew by over 20% during the preceding five years, signaling a significant improvement over the observed trend for 1997 to 2002 in the state. Those 34,500 biobusiness technology jobs in

---

Minnesota at the end of 2007 were associated with over \$2.1 billion in payroll and almost \$11 billion in revenue, spread over more than 670 enterprises in the state.<sup>3</sup>

### **Overview of Medical Devices**

Since 2002, Minnesota has enjoyed an encouraging positive turnaround in its competitive position in the medical devices industry. By the end of the decade it was second only to California in the number of medical devices jobs and it moved in to the top position (above California) in terms of its productivity as a state in generating medical devices employment, taking in to account the relative size of its economy and the state of the industry and the general economy nationwide. Despite significant (and improving) competition from a number of other states, Minnesota managed to regain and build upon its competitive position in the medical devices industry.

While most of the other competitor states (including California) lost medical devices jobs during the second half of the decade, the number of jobs in Minnesota in this field actually grew significantly. During that period, while the nation as a whole lost more than 11,000 medical devices jobs in the aggregate, the number of people employed in medical devices enterprises in Minnesota grew by over 4,500 people.

### **Overview of R&D in the Life Sciences**

“R&D in the life sciences” is the overarching label for research and development in biotechnology and research and development in other biology-related fields. It includes only R&D activities and not manufacturing activities.

The first statewide biobusiness assessment reported that between 1997 and 2002 Minnesota has been growing more slowly than the nation as a whole in employment in R&D in the life sciences. At that time the United States as a whole had enjoyed a growth of 149% in life sciences R&D employment during the previous half-decade whereas Minnesota's employment in the field had grown by only 52 percent. Since then, however, the situation has changed. During the half-decade following the previous Economic Census, total life sciences R&D employment in the United States dropped by about 19% and many states experienced painful drops much larger than that (e.g., New York experienced a 77% reduction). California experienced a reduction of 23 percent, following its previous rise of 134 percent. Minnesota managed to contain its reduction after 2002 to 8% only. In other words, Minnesota reversed its situation from being significantly below the national average prior to 2002, to being significantly above the national average after 2002, *vis-à-vis* employment growth in life sciences R&D.

Minnesota has apparently been doing something right during recent years, not just in the medical devices area, but also in the business of life sciences R&D.

### **Overview of Agri-bio and Bio-industrial Technology**

Agri-bio and bio-industrial technology is technology directed primarily towards applications in biological systems exterior the human body. Agri-bio and bio-industrial

---

<sup>3</sup> Source: Dr. Kelvin Willoughby, using data from the 1997 Economic Census, the 2002 Economic Census and the 2007 Economic Census of the U.S. Bureau of the Census.



technology may incorporate technical means from any field of technology, including biotechnology; but it must be directed towards applications in living systems or biology-related contexts. Agri-bio technology is focused on the application of biological technology in the field of plants and agriculture and bio-industrial technology is focused on the application of biological technology in industrial fields such as bio-materials, bio-processing, bio-energy, bio-based chemicals, food ingredients, and bio-remediation.

During the second half of the decade to 2007 employment in Minnesota in the agri-bio and bio-industrial technology industries increased by over 44% and the state's share of total national employment in the sector also rose. Ethanol production is the dominant sub-domain of Minnesota's agri-bio and bio-industrial technology industries.

While the recent performance of the state in this area is positive, not negative, the modest absolute scale of the growth compared with the growth that was enjoyed by some of the other states suggests that Minnesota may need to redouble its efforts. This may, for example, include identifying a niche (such as emerging technologies in ethanol production) where the state may have a chance to set the agenda in the nation. Nevertheless, notwithstanding the fact that a number of other states seem to have moved more aggressively than Minnesota in to the agri-bio and bio-industrial technology industry space during the last decade, it appears that Minnesota remains active in the area, leveraging some of its emerging capabilities in commercial life sciences R&D to develop new business models for innovation in agri-bio and bio-industrial technology. Some other U.S. states may be benefitting, in terms of employment generation, from Minnesota's efforts in this domain; but Minnesota's agri-bio and bio-industrial technology companies seem for now to be generating increased revenue for the state from their geographically dispersed activities.

### **Overview of Pharmaceuticals**

While Minnesota is a relatively minor player in the US pharmaceuticals industry, the scale of the industry in Minnesota is growing. During the five years leading up to the most recent Economic Census, total pharmaceuticals employment in Minnesota grew by 76 percent and the state's share of national pharmaceuticals employment increased significantly. Minnesota increased its productivity in generating both employment and enterprises in the pharmaceuticals industry; and Minnesota's performance in pharmaceutical entrepreneurship was greater than what one would expect, all other things being equal.

Minnesota's percentage growth in pharmaceuticals employment was in fact the highest of the eleven competitor states included in the assessment. The growth in pharmaceuticals employment for the nation as a whole during that period was less than one percent, and some states—e.g., New Jersey, New York, Utah and Iowa—actually lost jobs. Minnesota's employment growth in this sector—modest though it is in terms of absolute numbers—should therefore be treated with some respect.

Overall, Minnesota performs relatively more strongly in pharmaceuticals entrepreneurship than it does in generating growth in pharmaceuticals employment. Nevertheless, having said that, the state's performance in the generation of new jobs in pharmaceuticals in recent years is very encouraging.

## Conclusions

Figure 3 provides a summary of the empirical results of this project. The most important conclusion is that Minnesota increased its number of biobusiness technology jobs significantly during the five-year period between the two most recent Economic Censuses. During that time the state also increased its *productivity in generating biobusiness technology jobs relative to other states*. Minnesota managed to maintain its above-average level of competitiveness (measured by employment levels, weighted to take in to account the relative size of Minnesota's economy and the size of the biobusiness technology industry nationwide) continuously throughout the decade following 1997; and between 2002 and 2007 the state managed to significantly improve its relative position. In short, Minnesota managed to turn around its previous downward trend in biobusiness technology competitiveness into an impressive upward swing. The scale of the upwards shift in Minnesota's competitiveness, as indicated by its dynamic propensity for generating employment through biobusiness technology, was the greatest of any of the competitor states reviewed during the assessment project.

The salience for Minnesota, compared with other states (especially in areas of technological convergence) between the devices segment and other segments, was recognized in the previous statewide assessment report. As we enter the second decade of the Twenty First Century it appears to be imperative for Minnesota to enhance its capacity to leverage the strength of the medical devices segment of the biobusiness economy for the other segments. Accordingly, there may be value for enterprises in the other segments in the overall biobusiness technology industry to consciously seek further opportunities for leveraging the strength and momentum of the medical devices segment to their own advantage. Conversely, medical devices firms might find opportunities to further enhance their business by seeking ways to leverage innovations emanating from the other segments.

The leaders of Minnesota's impressive recent biobusiness technology resurgence might be able to energize their efforts to convert this resurgence in to a sustainable competitive advantage for the state through facilitating the enhancement of linkages between the medical devices segment and other segments of the biobusiness economy in Minnesota.

The first statewide assessment report for the BioBusiness Alliance of Minnesota ended with the following conclusion, regarding the biobusiness technology industries of Minnesota: *"... the biobusiness "train" has not yet left the station. However, we have discovered through our investigations that—metaphorically speaking—other states and other communities are busy investing in their own biobusiness "railway" systems, complete with tracks, stations, rights of way, new types of locomotives and new rail support services. Minnesota needs to plan and implement its next-generation "biobusiness rail system" with renewed vigor and urgency ... and in a manner that truly reflects the distinctive technological capabilities of the state. The dynamism, uniqueness and recently renewed growth of the employment and business activity in our state's biobusiness sector provides solid grounds for hope that the necessary steps can be taken to sustain Minnesota as a first-tier global player in the biobusiness fields where it can truly be among the best of the best."* This report of the second statewide assessment has shown that both the caution (about mounting competition from other states, amidst some faltering steps within the state) and optimism (about Minnesota's underlying capability to

respond to the challenge) expressed in that first report were justified. Some of Minnesota's competitor states have continued to enhance their position in biobusiness technology since 2002 thereby threatening the comfort of Minnesota's incumbent biobusiness technology enterprises; but in the mean time Minnesota has also apparently managed to make real progress in planning and implementing its "next generation biobusiness rail system" (to continue with the metaphor employed in the previous report). The upward swing in Minnesota's biobusiness technology fortunes since 2002 may provide inspiration and grounds for hope to the state's current biobusiness leaders.

**Executive Summary: Figure 3**

**Overall Economic Trends, Biobusiness Technology Industries  
(and the Macro-economy), Minnesota, 2002-2007**

Economic Variable	Medical Devices	R&D in the Life Sciences (excluding the academic sector)	Agri-bio and Bio-industrial Technology	Pharmaceuticals	Total Biobusiness Technology Industries	All Industries (in the macro-economy)
Number of employed people (in Minnesota)	Up	Down slightly	Up	Up	<b>Up</b>	Up slightly
Percentage of U.S. workforce	Up	Up slightly	Up	Up	<b>Up</b>	Down slightly
Number of Enterprises (in Minnesota)	Down	Up	Up	Down	<b>Down</b>	Up
Percentage of U.S. Enterprises	Up	Up	Down	Down slightly	<b>Up</b>	Down
Relative productivity in generating employment* 2002-2007	Up	Up	Up	Up	<b>Up</b>	Down slightly
Overall Competitiveness 2002-2007	Up	Up	Up slightly	Up slightly	<b>Up</b>	Stable
<i>Relative productivity in generating employment* 1997-2002</i>	<i>Down</i>	<i>Down</i>	<i>Down</i>	<i>Down</i>	<i>Down</i>	<i>Up slightly</i>
<i>Overall Competitiveness 1997-2002</i>	<i>Down</i>	<i>Down</i>	<i>Down</i>	<i>Stable</i>	<i>Down</i>	<i>Stable / Up slightly</i>

- As indicated by changes in the pertinent *Employment Density Index* over time.

# *Biobusiness 2010:*

## *Minnesota's Competitive Position in the Biobusiness Technology Industries*

### **1. Introduction**

This report summarizes the results of the second statewide biobusiness assessment conducted for the BioBusiness Alliance of Minnesota.

The first assessment, published in August 2006, consisted of two parts: (1) a systematic study of Minnesota and ten other states, designed to produce a baseline profile of Minnesota's biobusiness technology economy at the end of the most recent U.S. Economic Census and a comparison of Minnesota's competitive position, including strengths and weaknesses, with other U.S. states targeting areas of economic development similar to Minnesota; and, (2) a detailed "grassroots" census and study of biobusiness technology enterprises in Minnesota, profiling core technologies, products and markets of those enterprises, for the primary purpose of identifying appropriate focal areas for technological investment and development in biobusiness in Minnesota. The comparative study focused on business enterprises only, whereas the grassroots study also included academic and non-for-profit research organizations in its purview.<sup>4</sup>

The second statewide biobusiness assessment, conducted during the latter months of 2010, has followed the general methodology of the original comparative study, updated to include new data on industry developments that have become available following the release during 2010 of the results of the 2007 U.S. Economic Census. The 2010 assessment exercise, the results of which are contained in this report, consisted only of the comparative assessment of Minnesota and ten other states; it did not include a repetition of the original 2006 grassroots study.

The primary goals of the 2010 statewide biobusiness assessment project were similar to those of the 2006 project: to provide a baseline assessment of biobusiness technology in Minnesota against which the state may be benchmarked; and, to provide thoughtful, well-researched recommendations to help guide the state in becoming more competitive in specific areas of biobusiness. An additional goal of the 2010 project was

---

<sup>4</sup> For the full report and executive summary of the original statewide assessment project, see, *Biobusiness: Minnesota's Present Position and Future Prospects*, Report of the Statewide Biobusiness Assessment Project of the BioBusiness Alliance of Minnesota (St. Louis Park: BioBusiness Alliance of Minnesota, August 2006). That project was co-chaired under the auspices of the BioBusiness Alliance of Minnesota by Vincent Ruane and Kelvin Willoughby (Dale Wahlstrom, Chairman of the Board; Jeremy Lenz, Project Executive). The principle author of the 2006 report (which may be downloaded from the website of the BioBusiness Alliance, at [www.biobusinessalliance.org](http://www.biobusinessalliance.org)) was Kelvin Willoughby.

to document and analyze changes that have taken place in Minnesota's biobusiness technology industries—specifically, increases or decreases in key economic variables in the constituent industries, in comparison with changes in equivalent industries in the selected competitor states and in the nation as a whole—during the time that has passed since the date of the previous U.S. Economic Census in 2002.

## 2. Basic Profile of Minnesota's Biobusiness Economy

Before elaborating the full results of this study it will be useful to provide an overall picture of Minnesota's biobusiness economy together with some definitions of basic concepts. A full list of definitions and accompanying explanations is provided in Appendix 1.

*Biobusiness is economic activity devoted to the development or commercialization of bioscience or bioscience-related technologies, products or services.* In other words, biobusiness is technology-based economic activity that utilizes or is informed by biology.

Biobusiness deals with the spectrum of enterprises from start-ups to established firms, together with associated infrastructure and support services (such as those provided by legal service firms, management consultants, marketing organizations, accountants, lobbyists, investors, regulatory affairs specialists, or specialized property developers). The focus of this report is on a narrower set of enterprises: those whose primary business is the development or commercialization of what may be labeled as “biobusiness technology.” Formal analysis of the infrastructure and support services associated with biobusiness may be addressed elsewhere.

*Biobusiness technology is technology devoted to the biological domain, as either a system of tools or as a field of application.*

Put simply, biobusiness technology is technology focused on biology. It is the technological foundation of biobusiness. As explained further in Appendix 1, biobusiness technology may be grouped in to three broad and overlapping technological sub-domains: biotechnology; human health technology; and agri-bio & bio-industrial technology. An organization whose business is based on any of these three domains may be labeled a “biobusiness technology enterprise” (BTE).

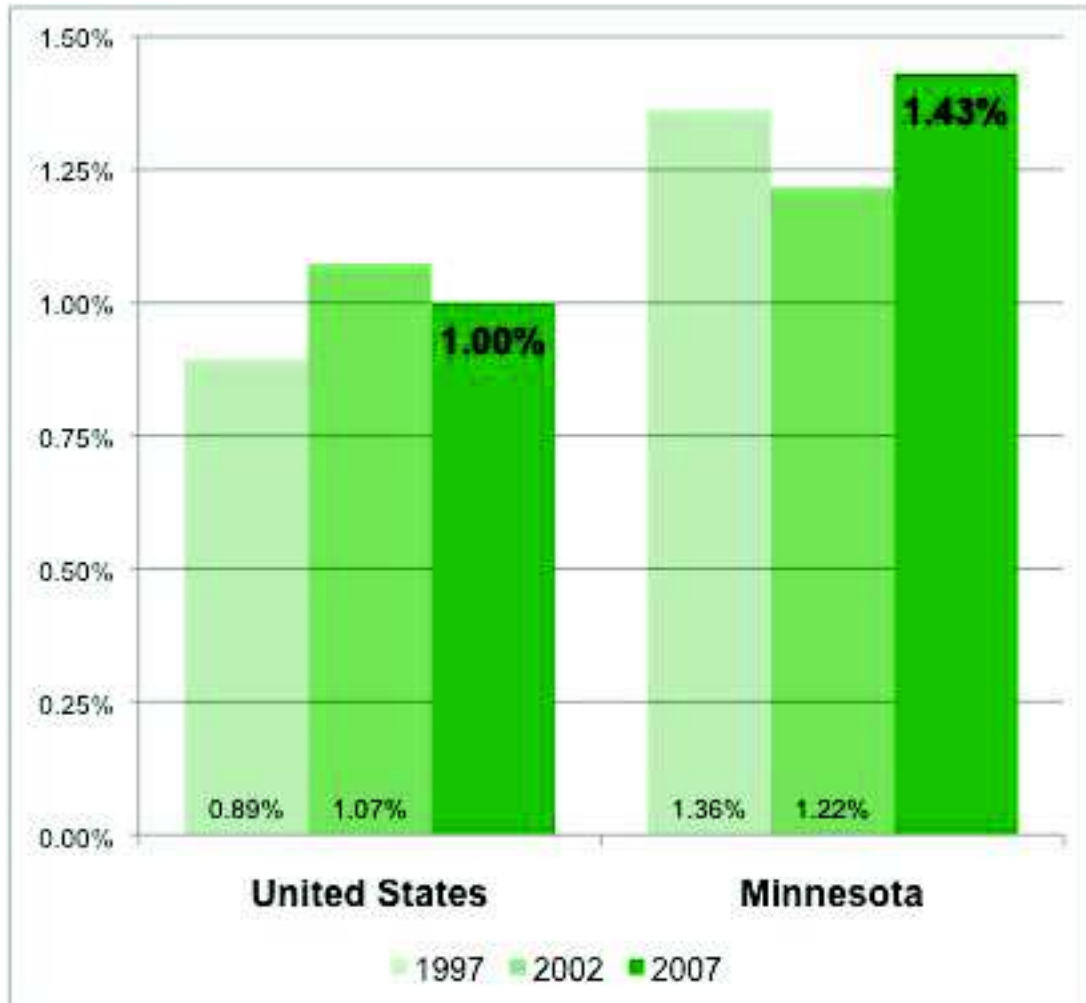
By late 2007, the most recent year for which national data from the U.S. Economic Census is available, the biobusiness technology sector in the United States consisted of over 36,500 establishments, almost 1.2 million paid employees, an aggregate annual payroll of over \$74 billion, and aggregate annual revenues of over \$450 billion.<sup>5</sup> The biobusiness technology sector in the U.S. is substantial. In addition, the average wage in the bioscience technology sector (at \$64,116, in 2007) was almost \$23,000

---

<sup>5</sup> These numbers were calculated by Dr. Kelvin Willoughby using data from the 2007 U.S. Economic Census of the U.S. Bureau of the Census, using a selection of industry categories listed in Appendix 2. The data used to construct Figures 1 & 2 were also drawn from that source. These data exclude employment inside universities, hospitals and other not-for-profit organizations involved in biobusiness.

greater than the average private sector wage.<sup>6</sup> Biobusiness technology is an important field of industry from the point of view of economic development.

**Figure 1: Biobusiness Technology Employment as a Percentage of Employment in All Industries—United States and Minnesota, 1997, 2002 & 2007**

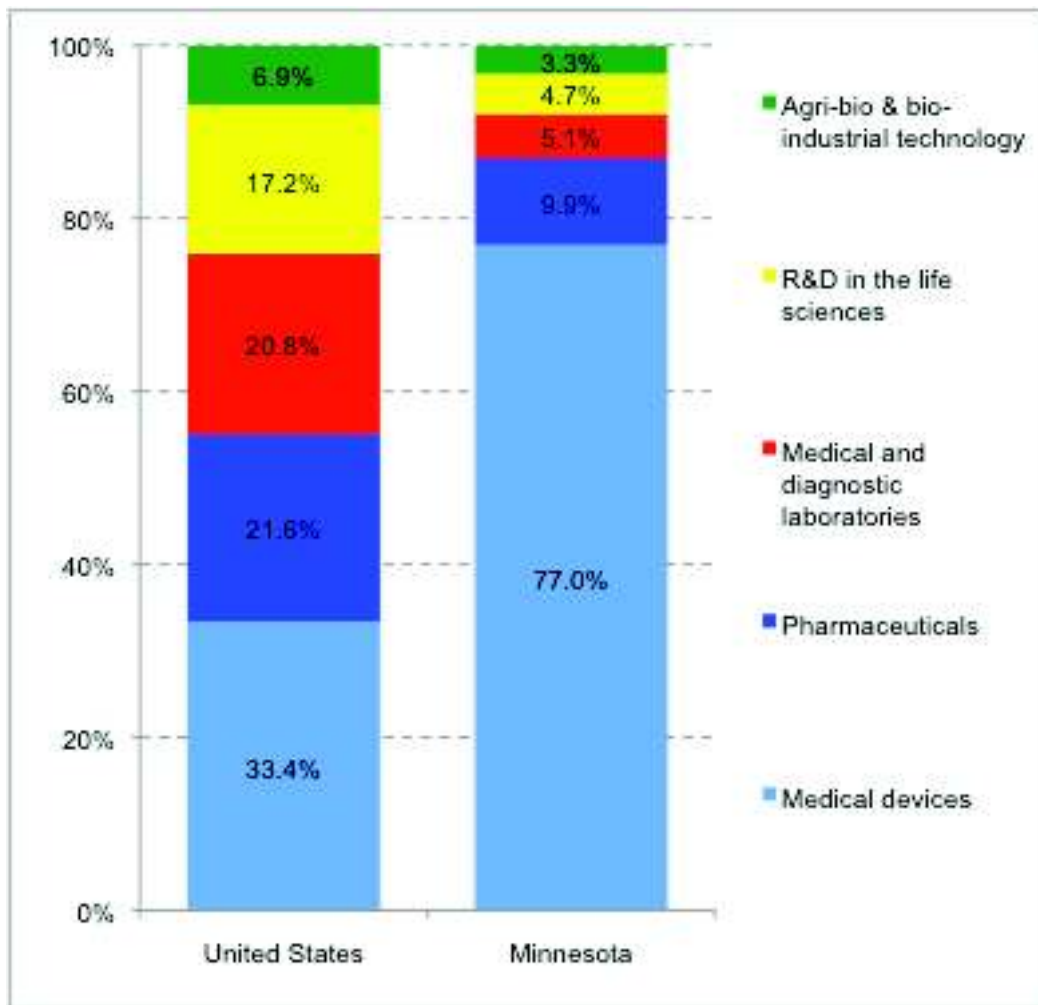


As shown in Figure 1, Minnesota's economy is more heavily oriented towards biobusiness technology employment than is the economy of the whole country. In fact, biobusiness technology employment in 2007, as a proportion of employment in all industries, was 42% greater in Minnesota than in the nation as a whole. While the numbers have fluctuated over time, Minnesota remained consistently above the national norm throughout the previous decade. This means that Minnesota's future employment prospects are more dependent than most other states on what happens to its biobusiness sector. In short, more is at stake for Minnesota in biobusiness than is the case for most other states.

<sup>6</sup> These wage figures were also calculated by Dr. Kelvin Willoughby using data from the 2007 U.S. Economic Census of the U.S. Bureau of the Census.



Figure 2A: Percentage of Total Biobusiness Technology Employment in Each Industry—United States and Minnesota, 2007



As shown in Figure 2A, Minnesota also has a distinctive biobusiness technology profile. Compared with the rest of the country, our state's biobusiness sector is heavily dependent upon the medical devices segment. In fact, the percentage of biobusiness employment accounted for by the medical devices segment is more than twice as large in Minnesota than it is in the nation as a whole. Figures 2A, 2B and 2C together reveal that the ratio of Minnesota to the nation (in the respective percentage of biobusiness employment accounted for by the medical devices segment) increased over the previous decade, from 202% in 1997 to 233% in 2007.<sup>7</sup> The relationship (especially in areas of technological convergence) between the devices segment and other segments therefore seems to be salient for Minnesota, compared with other states.

<sup>7</sup> These percentages were calculated as follows: 202% = 80.9 / 40.0 and 233% = 77.8 / 33.4 (numbers extracted from data in Figures 2A and 2C).

Figure 2B: Percentage of Total Biobusiness Technology Employment in Each Industry—United States and Minnesota, 2002

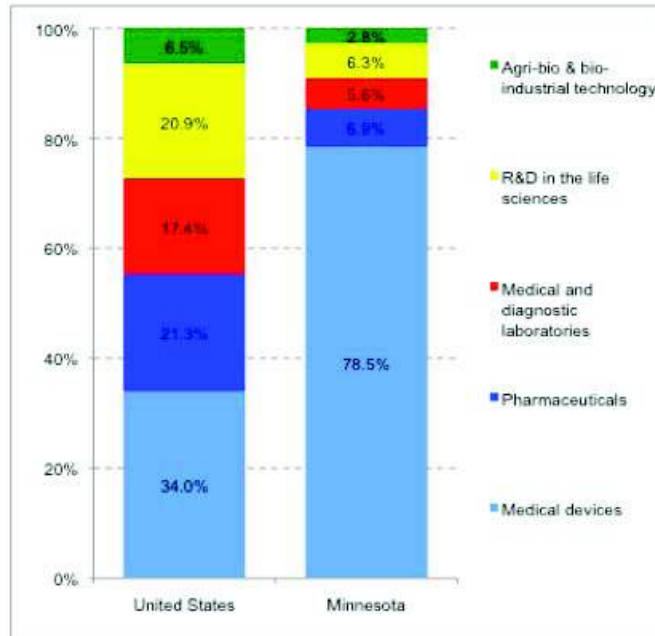


Figure 2C: Percentage of Total Biobusiness Technology Employment in Each Industry—United States and Minnesota, 1997

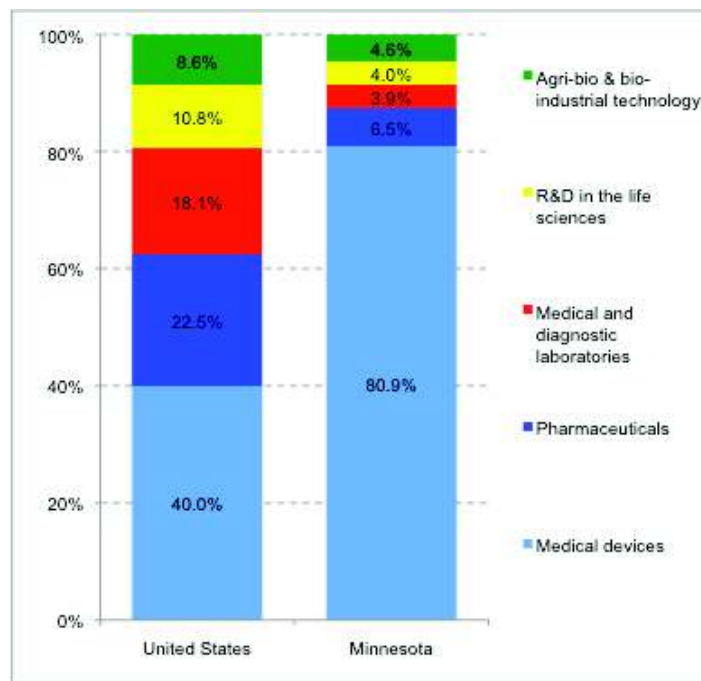
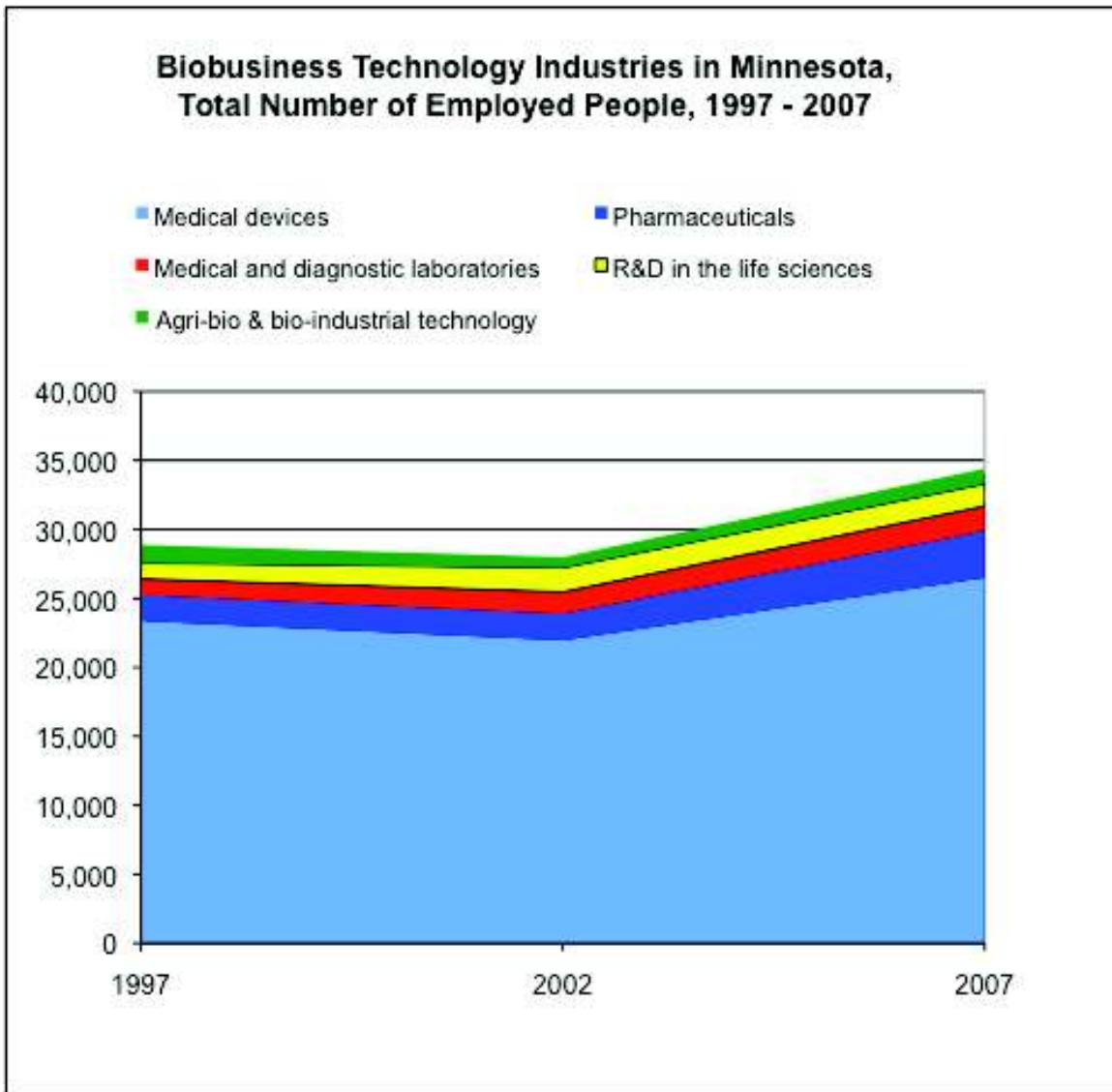


Figure 3: *Biobusiness Technology Industries in Minnesota, Total Number of Employed People, 1997-2007*



What about the absolute size of Minnesota's biobusiness technology sector? By late 2007, the most recent year for which data from the U.S. Economic Census is available, the state was home to just over 34,000 biobusiness technology employees. Additionally, total biobusiness technology employment in Minnesota grew by over 20% during the preceding five years, signaling a significant improvement over the observed trend for 1997 to 2002 in the state (see Figure 3). Those 34,000 biobusiness technology jobs in Minnesota at the end of 2007 were associated with over \$2.1 billion in payroll and almost \$11 billion in revenue, spread over more than 670 enterprises in the state.<sup>8</sup> It is worth noting that the total economic impact would be even greater if all biobusiness

<sup>8</sup> Source: Dr. Kelvin Willoughby, using data from the 1997 Economic Census, the 2002 Economic Census and the 2007 Economic Census of the U.S. Bureau of the Census.

enterprises were taken into account, as opposed to solely including biobusiness technology enterprises, as has been done for the analysis in this report.<sup>9</sup>

The share of Minnesota's economy accounted for by biobusiness technology—measured by either employment or industry revenue—increased over the five years between the two most recent U.S. Economic Censuses (2002 and 2007). The share of employment in all industries accounted for by biobusiness technology jobs rose 15% above its 2002 level by 2007, and the share of revenue in all industries accounted for by revenue from biobusiness technology enterprises rose 26% above its 2002 level by 2007.<sup>10</sup>

Minnesota has a significant presence in biobusiness technology; and biobusiness technology plays a significant role in Minnesota's economy.

### 3. Overview of Methodology and Data Sources

The publicly available data sources that are useful for conducting comparative industry competitiveness studies across the United States do not lend themselves very neatly to the analysis of biobusiness or, more particularly, biobusiness technology. The best that can be done is to select a group of industry categories to act as a proxy for biobusiness technology as defined and illustrated in Appendix 1.

The primary data source that has been drawn upon in this report for analysis of Minnesota's competitive position is the periodic Economic Census conducted by the U.S. Census Bureau, 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"), which was implemented for the first time in 1997. The most recent Economic Census data were generated at the close of 2007 and were released during 2010. Thus, the most recent census data available at the time of writing this report are 2007 data. This report also draws upon data from the two previous Economic Censuses, from 1997 and 2002, thus allowing us to conduct analysis over a period of ten years.

The new NAICS categories are 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 a 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. As a consequence, it is impossible to find a set of NAICS codes that corresponds exactly to the group of

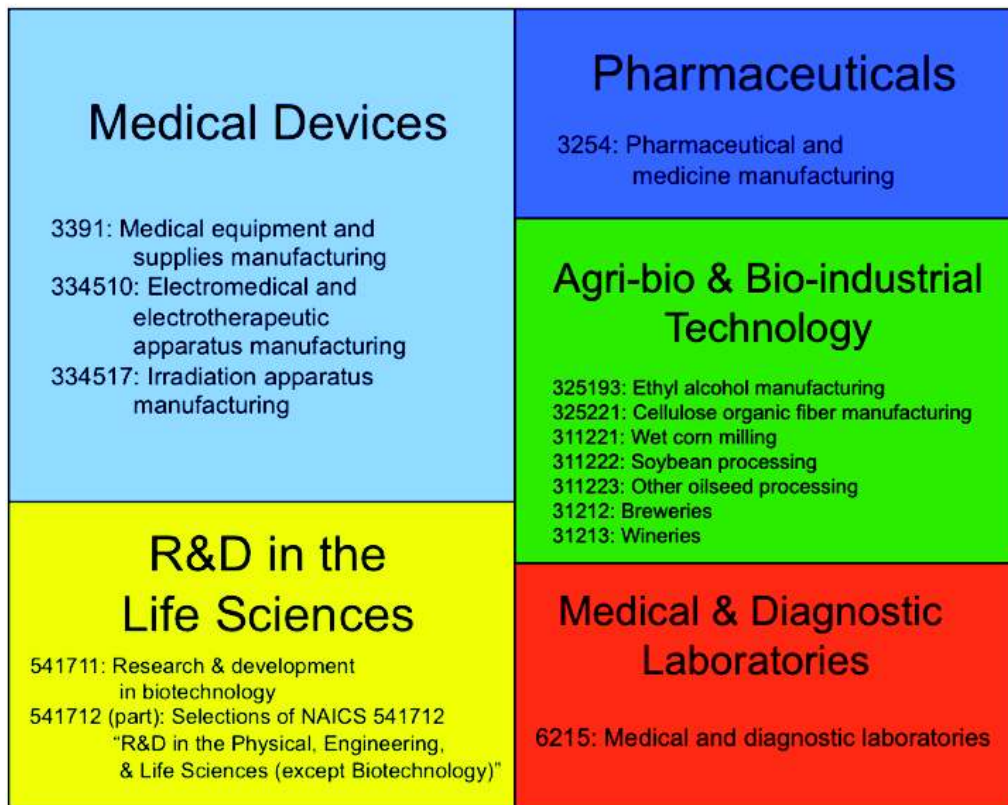
<sup>9</sup> For example, if the scope of the analysis were broadened to include "biobusiness clinical services" (from hospitals and veterinary service providers) in 2007, the economic impact would rise to about \$25 billion in revenue, about \$8 billion in payroll and about 150,000 jobs, spread across about 1,600 enterprises.

<sup>10</sup> Source: Dr. Kelvin Willoughby, using data from the 2002 Economic Census and the 2007 Economic Census of the U.S. Bureau of the Census.

biological technology industries that are labeled here collectively as “biobusiness technology” industries.

Figure 4: *Biobusiness Technology Industries (Map of NAICS-based categories - 2007)*

## Biobusiness Technology Industries (Map of NAICS-based categories – 2007)



Nevertheless, after careful study of the North American Industrial Classification System, a group of NAICS codes was selected to act as a rough approximation for the set of enterprises that together constitute the biobusiness technology sector. The results are summarized in Figure 4. The categories covered in Figure 4 may be seen as a practical but inexact substitute for the biobusiness categories portrayed in Appendix 1. Data were collected and analyzed for each of the NAICS industry categories listed in Figure 4, covering both enterprises with paid employees and enterprises without paid employees, for 1997, 2002 and 2007. Precise definitions of each industry group included in Figure 4 are provided in Appendix 2 at the end of this report. Some minor changes to the NAICS classification system, pertinent to this study, which were adopted between 2002 and 2007 Census, were implemented by the U.S. Census Bureau during the 2007 Economic Census. A systematic mapping of the older and newer NAICS categories employed in



this report, to indicate the correspondence between the 2007 data set and the two previous data sets, is provided in Appendix 3.

In an effort to fit in as best as possible with assumptions and concepts embedded in the NAICS categories, biobusiness technology was subdivided into five sub-categories: medical devices, pharmaceuticals, R&D in the life sciences, agri-bio & bio-industrial technology, and medical & diagnostic laboratories.

The three combined categories of medical devices, pharmaceuticals, and medical & diagnostic laboratories illustrated in Figure 4 (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 35 in Appendix 1. The aggregated collection of NAICS categories labeled in Figure 4 as “agri-bio & bio-industrial technology” is treated as a rough proxy for the biobusiness technology category of the same name in Appendix 1 (Figure 35). The NAICS category in Figure 4 labeled as “R&D in the life sciences” is treated here as a rough proxy for the biobusiness technology category labeled in Appendix 1 (Figure 35) as “biotechnology,” except that it focuses on research and development activities rather than manufacturing. 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 the category labeled as “agri-bio & bio-industrial technology” in Appendix 1 (Figure 35). 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 R&D” is a reasonable compromise to help us deal with the realities of publicly available data sets.

The “Research & development in the life sciences” category—as mentioned above—includes only R&D activities and not manufacturing activities. This category, “R&D in the life sciences,” is comprised of firms from both NAICS 541711 (R&D in biotechnology) and a portion of firms from NAICS 541712 (R&D in the physical, engineering, and life sciences (except biotechnology)), representing only the life sciences sub-category of NAICS 541712. The official definition for NAICS 541711 is: “... establishments primarily engaged in conducting biotechnology research and experimental development. Biotechnology research and experimental development involves the study of the use of microorganisms and cellular and biomolecular processes to develop or alter living or non-living materials. This research and development in biotechnology may result in development of new biotechnology processes or in prototypes of new or genetically-altered products that may be reproduced, utilized, or implemented by various industries.” The definition for the life sciences sub-category of NAICS 541712 (previously NAICS 5417102) is: “... establishments primarily engaged in conducting research and experimental development in medicine, health, biology, botany, ... agriculture, fisheries, forests, pharmacy, and other life sciences including veterinary sciences.”<sup>11</sup> This sub-category excludes biotechnology R&D, strictly speaking, as defined in NAICS 541711.

---

<sup>11</sup> A detailed explanation of how the calculations were made for the life sciences component of NAICS 541712 (R&D in the physical, engineering, and life sciences (except biotechnology) for 2007, together with a concordance for the pertinent parts of NAICS 2002 and NAICS 2007, is provided in Appendix 3 at the end of this report.



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 (*vis-à-vis* Figure 35) are included within the “Research & development in the life sciences” category (in Figure 4). 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 (in Figure 4).

Having defined and illustrated what is meant by “biobusiness technology” (primarily business centered on biological technology), and having provided a general profile of the biobusiness technology sector in Minnesota, it is appropriate to now review our state’s competitive position alongside other important biobusiness states. The following sections of this Report compare 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: California, Iowa, Massachusetts, New Jersey, New York, North Carolina, Ohio, Utah, Washington and Wisconsin. The list of ten states is not meant to be exhaustive; it is intended to be indicative for competitive analysis. The list also provides a wide spectrum of states from large to small, urban to rural, coastal and heartland, proximate to Minnesota and distant.<sup>12</sup>

## 4. Biobusiness Technology

Figure 5 plots the total employment level for the biobusiness technology industries (calculated using the NAICS codes as proxies) in Minnesota and the ten other selected states. California, with over 200,000 people employed in biobusiness technology enterprises, clearly leads the nation in biobusiness technology. About 30% of those jobs were added since 1997 and, while the state has lost some ground since 2002, California’s overwhelming leadership position is still robust.

California is followed in the distance by a few states that are positioned in the second tier *vis-à-vis* biobusiness technology employment overall: New Jersey, Massachusetts and New York. These states also dominate the second tier for employment in life sciences R&D, with the exception of North Carolina (the position of which has risen dramatically during the last decade), and also the second tier for employment in the medical devices industry, with the exception of Minnesota. Minnesota is the dominant second tier player in medical devices but currently just a minor player in life sciences R&D.<sup>13</sup>

<sup>12</sup> All of the calculations and figures reported in this Report dealing with Minnesota’s competitive position were produced by Dr. Kelvin Willoughby drawing upon data from the 1997, 2002 and 2007 U.S. Economic Censuses.

<sup>13</sup> See Figure 11 and Figure 17 in later sections of this Report for details about employment in medical devices and R&D in the life sciences.

Figure 5: Employment, Biobusiness Technology Industries—1997, 2002 & 2007

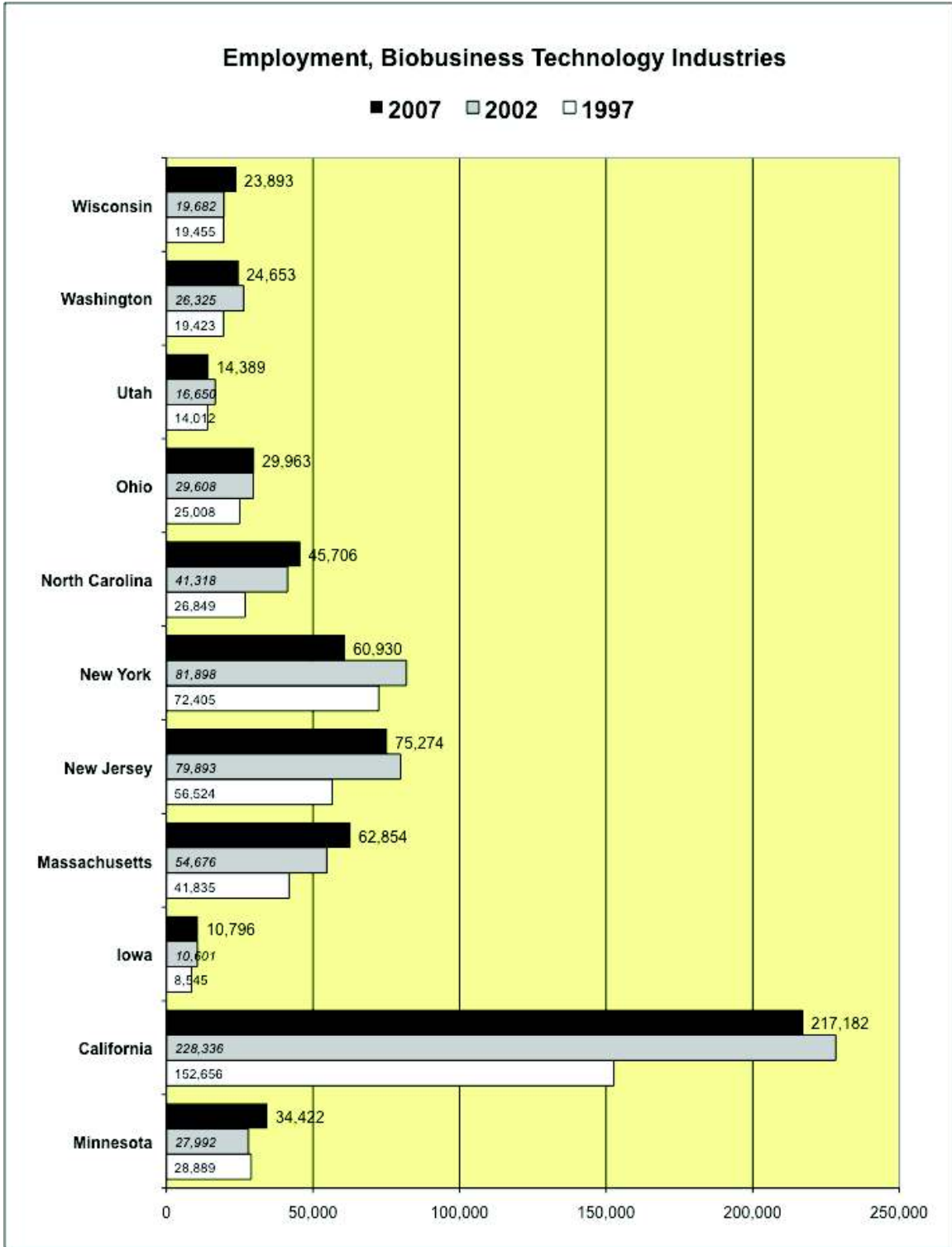
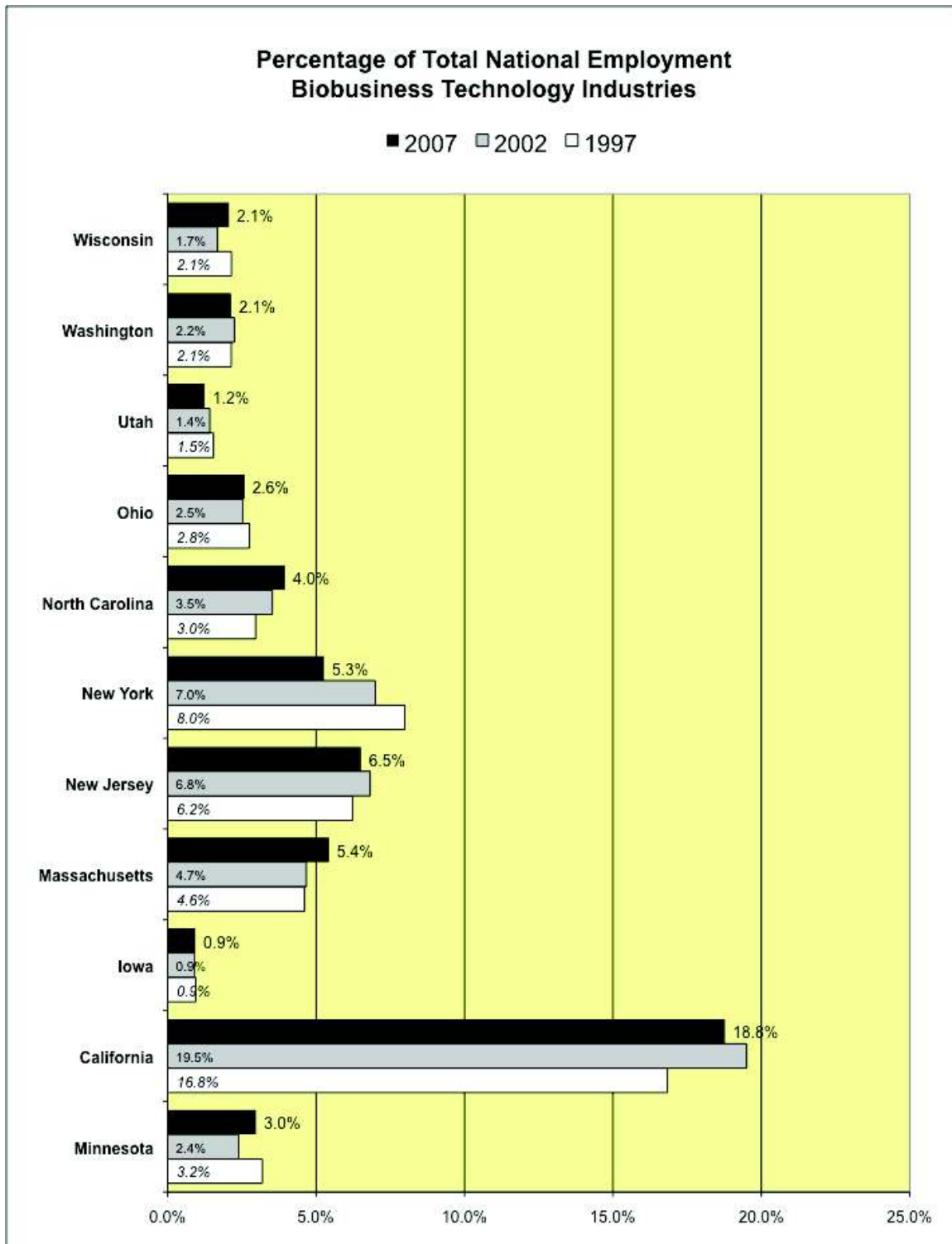


Figure 6: Percentage of Total National Employment in Biobusiness Technology Industries—1997, 2002 & 2007



A bright observation for Minnesota, from Figure 5, is that **employment in Minnesota's biobusiness technology enterprises grew by over 20%** from 2002 to 2007, more than making up for the lackluster performance during the previous half-decade. This news is especially encouraging, since Minnesota was the only state out of eleven that actually appeared to lose a small number of biobusiness technology industry employment during the five years from 1997 to 2002.<sup>14</sup> By the latter half of the first decade of the new millennium, Minnesota was obviously doing something right to nurture its competitiveness in biobusiness technology.

The groundswell (from stalled to positive) of Minnesota's overall fortunes in biobusiness technology employment during the five years to 2007 is doubly encouraging in view of the fact that two of the state's rivals in the third tier during 2002—Ohio and Washington—failed to make comparable progress. North Carolina, on the other hand, appears to be a state for Minnesota to carefully watch. In 1997 total biobusiness technology employment in North Carolina was lower than that of Minnesota but ten years later it was significantly higher.

Figure 6 takes the same data that were used to construct Figure 5 but expresses them as percentages of the national total, rather than as absolute employment numbers. The “national total” here refers to the total of the whole of the United States, not just the total of the eleven comparison states that are the focus for our analysis. California once again is the overwhelming leader, despite losing ground slightly in the face of stiff competition from other states during the second half of the decade. California managed to maintain its strong national position despite its widely touted “inhospitable business climate” (due to high real estate prices, high taxes and high wages). Minnesota's share of the national total increased during the five years to 2007 by one half of one percent to 2.9 percent. Of the strong second tier states, Massachusetts was the only one that managed to increase its share of the national employment total; although, as previously noted, in this regard North Carolina appears to be moving steadily from the third tier to the second tier.

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 7, which was produced for this purpose, reveals that during the latter half of the decade in question all eleven states underwent a reversal of their previous upward trend in biobusiness technology enterprise creation. Between 2002 and 2007 all eleven states experienced a decline in their number of locally domiciled biobusiness technology enterprises. This fact suggests that national factors, unrelated to the peculiarities of each state, drove consolidation within the industry. Minnesota, which was unable to escape this national trend, experienced a contraction of 26% in the number of biobusiness technology enterprises claiming the state as their home. California, for example, experienced a contraction of 35%, New Jersey experienced a contraction of 37% and New York experienced a contraction of 45 percent.

---

<sup>14</sup> The forecast of a post-2002 overall turnaround in biobusiness technology employment for Minnesota that appeared in the first statewide assessment report was thus affirmed by the results of the 2007 Economic Census released in 2010 (see, *Biobusiness: Minnesota's Present Position and Future Prospects*, Report of the Statewide Biobusiness Assessment Project of the BioBusiness Alliance of Minnesota (St. Louis Park: BioBusiness Alliance of Minnesota, August 2006), pages 12 & 17).

Thus, while Minnesota experienced a contraction in its biobusiness technology enterprise population during the half-decade between 2002 and 2007, it actually managed to resist the national trend towards consolidation more successfully than did its larger competitor states. It is also important to recall that, while the number of enterprises dropped, the total number of people employed actually increased. Thus, there was no net economic loss from the consolidation. The average size of biobusiness technology enterprises in Minnesota increased during the half-decade following 2002 from 31 people to 51 people per firm. The comparable increase for the biobusiness technology industry as a whole, across the United States (all 50 states), was from 21 people to 32 people per firm. Thus, not only did the average size of biobusiness technology firms in Minnesota increase to a greater degree than occurred in equivalent firms across the whole nation, but the rate of growth in firm size was greater in Minnesota than it was for the United States as a whole.

At the end of the decade, California led the pack again as the sole first tier state, with just over 6,200 biobusiness technology enterprises, compared with 670 in Minnesota.<sup>15</sup> New York's previous position as the sole second tier state (*vis-à-vis* the number of enterprises) was undermined by the wave of consolidations, contractions and losses it experienced. By the end of the decade New York came close to joining the third tier of biobusiness technology enterprise states (which might more aptly be described now as the "new second tier"), together with New Jersey, Massachusetts, Ohio, North Carolina and Washington.

In the minds of some observers, California's extraordinary position should be discounted due to the fact that California's population and economy are both very large; and some might even argue that comparisons of a large state such as California with smaller states, such as Minnesota, is simply not appropriate ... like comparing apples and oranges. A similar argument might also have been directed towards larger states such as New York, at least until 2002. It is therefore 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 other things being equal, one would expect to find a large-scale industry (of a specified kind) in a large community, and a correspondingly 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*

---

<sup>15</sup> Unless otherwise indicated, all references in this report to "the decade" will denote the ten years from 1997 to 2007 (i.e., the period covered by the data reported in all the charts and graphs).

Figure 7: Enterprises, Biobusiness Technology Industries—1997, 2002 & 2007

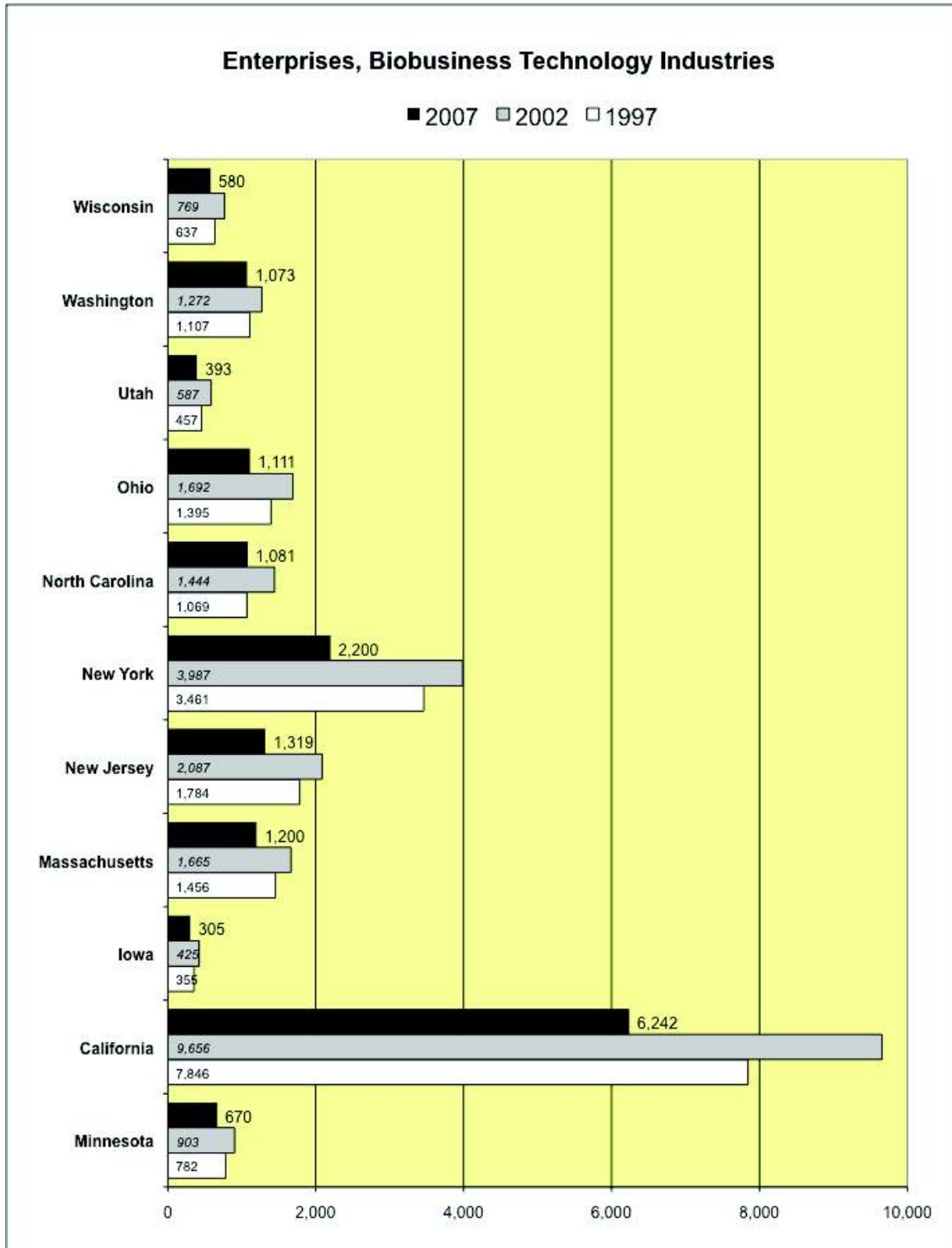
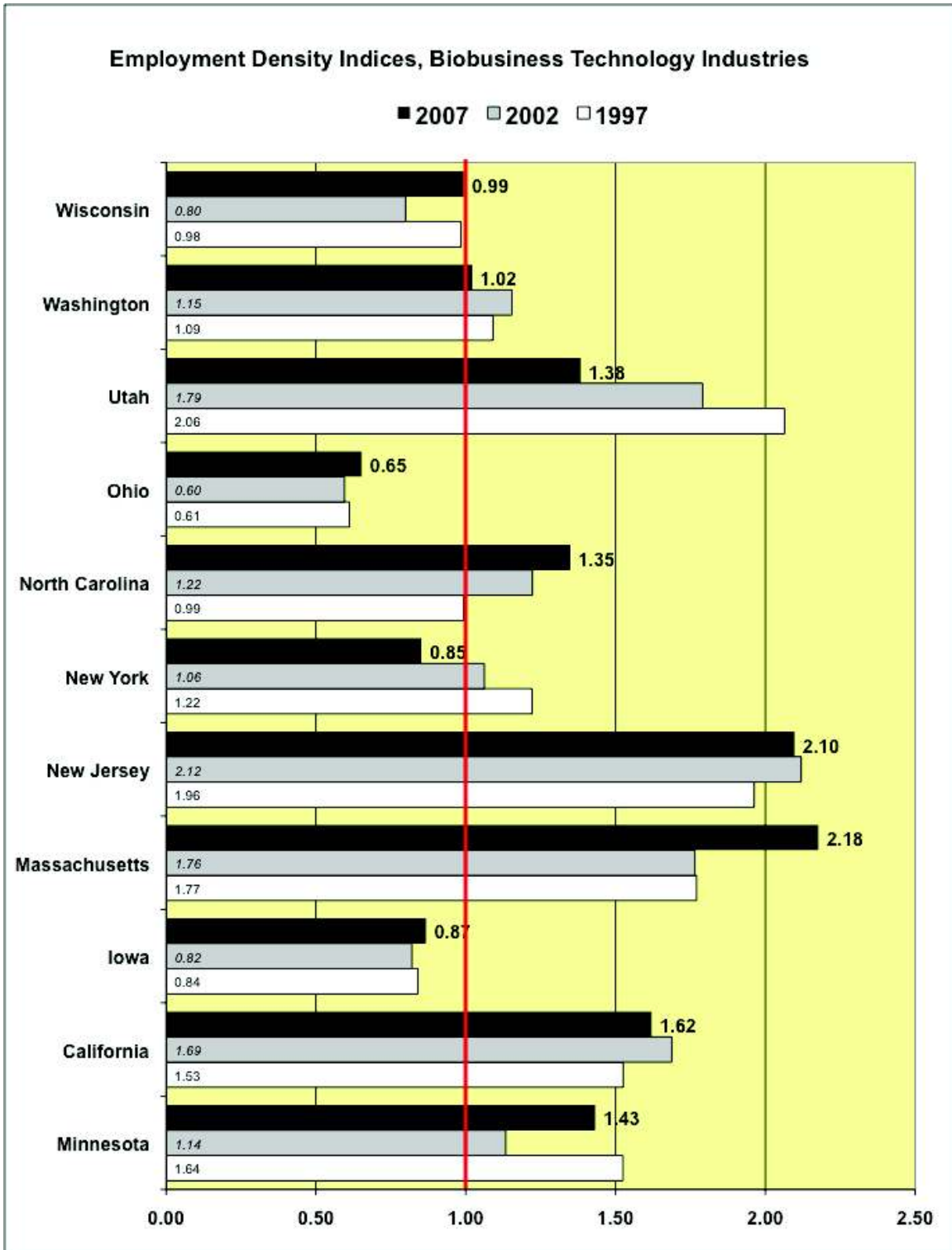




Figure 8: Employment Density Indices, Biobusiness Technology Industries—1997, 2002 & 2007



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 strength 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.<sup>16</sup>

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. Appendix 4 provides a detailed explanation of industry density 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.

Figure 8 plots the biobusiness technology employment density indices for Minnesota and the ten other states. The competitive states in 2007, in descending order of strength in generating biobusiness technology jobs, are: Massachusetts, New Jersey, California, Minnesota, Utah, North Carolina and Washington. From the point of view of employment generation in biobusiness technology industries, Minnesota is one of the “competitive” states (i.e., it scores an employment density index of greater than 1.0). New York, on the other hand, slipped below the competitiveness threshold during the years to 2007.

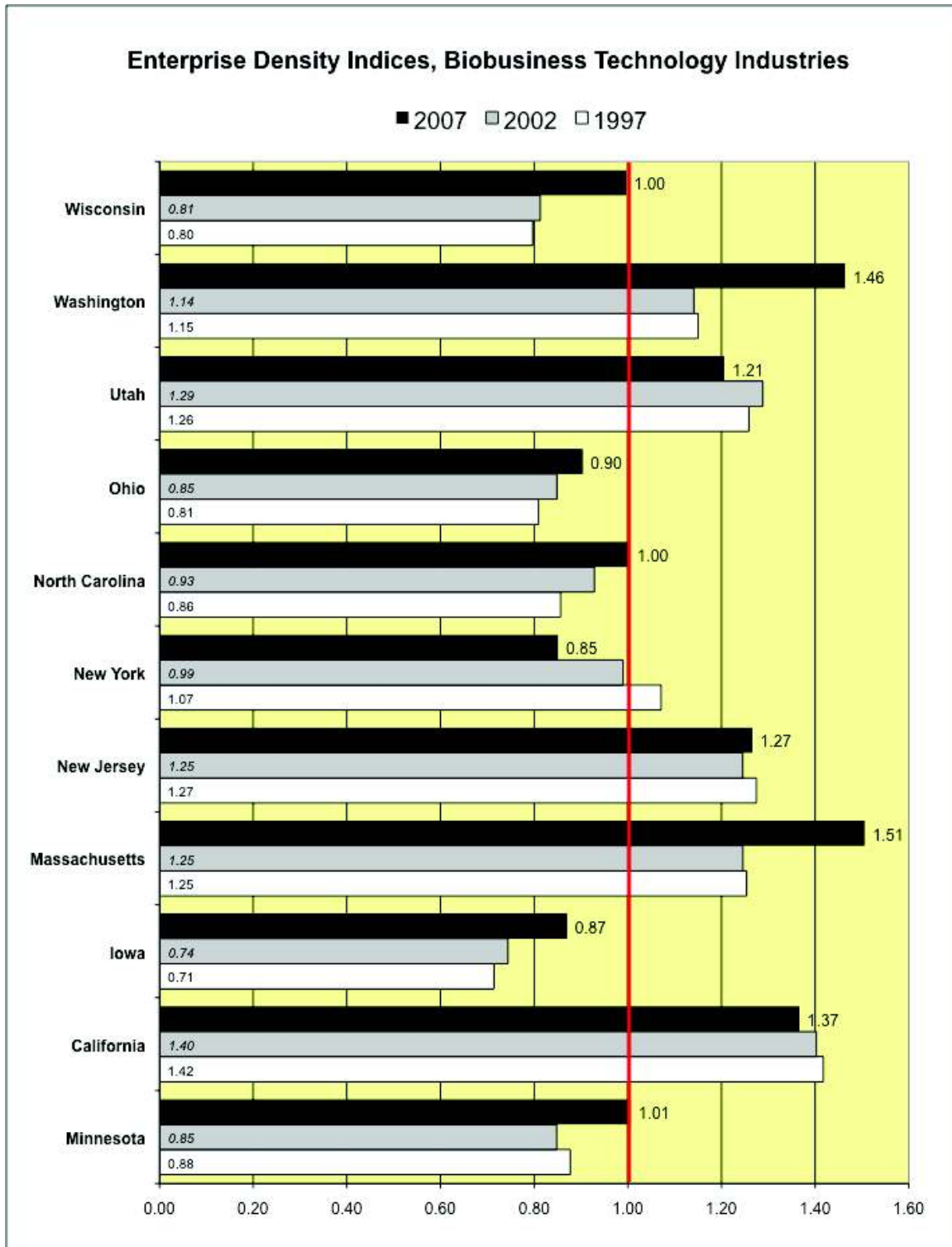
Minnesota managed to maintain its above-average level of competitiveness (*vis-à-vis* employment density) continuously throughout the decade following 1997; and between 2002 and 2007 the state managed to significantly improve its relative position. Minnesota’s biobusiness technology employment density index increased from 1.14 in 2002 to 1.43 in 2007.

This improvement in the performance of Minnesota since the time of the previous U.S. Economic Census is encouraging. **Not only did Minnesota increase its number of biobusiness technology jobs during the second half of the decade, the state also increased its productivity in generating biobusiness technology jobs relative to other states.** In short, Minnesota managed to turn around its previous downward trend in biobusiness technology competitiveness into an impressive upward swing.

---

<sup>16</sup> In some academic disciplines the particular kind of industry density index labeled here as an “employment density index” is known as a “location quotient.”

Figure 9: Enterprise Density Indices, Biobusiness Technology Industries—1997, 2002 & 2007



The significance of this positive turnaround may be better appreciated when it is recognized that during the previous half-decade (from 1997 to 2002) Minnesota's biobusiness technology employment density index actually dropped significantly—in fact it dropped further than any of the other comparison states—during a time when the majority of the eleven states either increased their biobusiness technology employment density indices or remained steady.

The discouraging picture that emerged after the 2002 Economic Census led to the following call being included in the previous statewide assessment report of the BioBusiness Alliance of Minnesota: “The results presented here ... point to the need for concerted effort by Minnesotans to improve the state's future competitiveness in the biobusiness technology industry.”<sup>17</sup> The objective economic facts that became available to us during 2010 suggest that the call was heeded by Minnesota's biobusiness leaders.

Figure 9 plots another type of industry density index for biobusiness technology for the eleven competitor states: an enterprise density index.

As was the case with its productivity in generating biobusiness technology *employment*, Minnesota also managed to turn around its position *vis-à-vis* productivity in generating biobusiness technology *enterprises* during the second half of the decade. Minnesota's biobusiness technology enterprise density index increased from 0.85 in 2002 to 1.01 in 2007. In other words, it rose—along with Wisconsin and North Carolina—to the cusp of competitiveness in biobusiness technology entrepreneurship (signaled by an enterprise density index of 1.0 or thereabouts). **In short, Minnesota managed to become more entrepreneurial in biobusiness technology following 2002.**

Over the whole decade covered by this study California managed to maintain a very high biobusiness technology enterprise density index, in the vicinity of 1.4. Thus, as was pointed out in the previous study (conducted five years ago), California earned its dominant position in the biobusiness technology world with above average performance, not simply as a result of its large economy and population, as some commentators have been tempted to aver. Conversely—using the same kind of logic—the data summarized in Figure 9 reveal that New York's declining absolute position in both the employment ranks (see Figure 5) and the enterprise ranks (see Figure 7) for biobusiness technology in the United States reflects a real decline in that state's overall competitiveness *vis-à-vis* biobusiness technology, rather than anything to do with shifts in the relative size of New York's economy and population compared with various high-growth regions of the United States.

The spectacular performers in biobusiness technology entrepreneurship over the second half of the decade, as revealed in Figure 9, were Massachusetts and Washington, both of which managed to surpass California as the leader *vis-à-vis* productivity in generating new biobusiness technology enterprises. These results, especially when the strong (although recently weakened) position of Utah is taken in to account, reveal that when it comes to entrepreneurship in biobusiness technology, the relative size of states has only marginal relevance, if any, in determining competitiveness.

---

<sup>17</sup> *Biobusiness: Minnesota's Present Position and Future Prospects*, Report of the Statewide Biobusiness Assessment Project of the BioBusiness Alliance of Minnesota (St. Louis Park: BioBusiness Alliance of Minnesota, August 2006), page 21.

Figure 10A: Percentage Change in Employment Density Indices, 1997-2002, Biobusiness Technology Industries

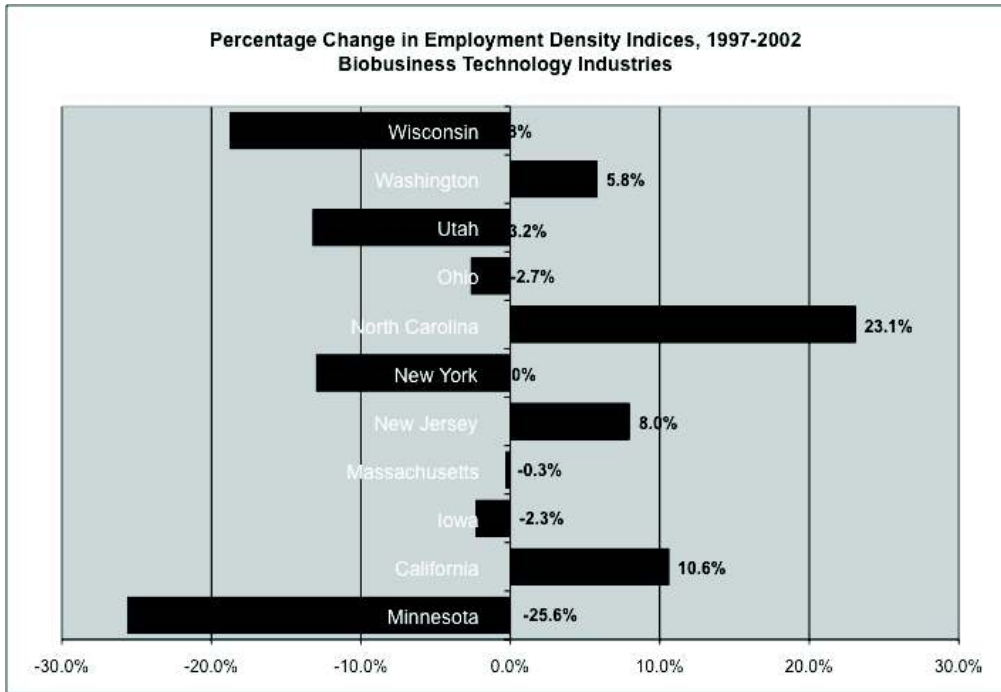
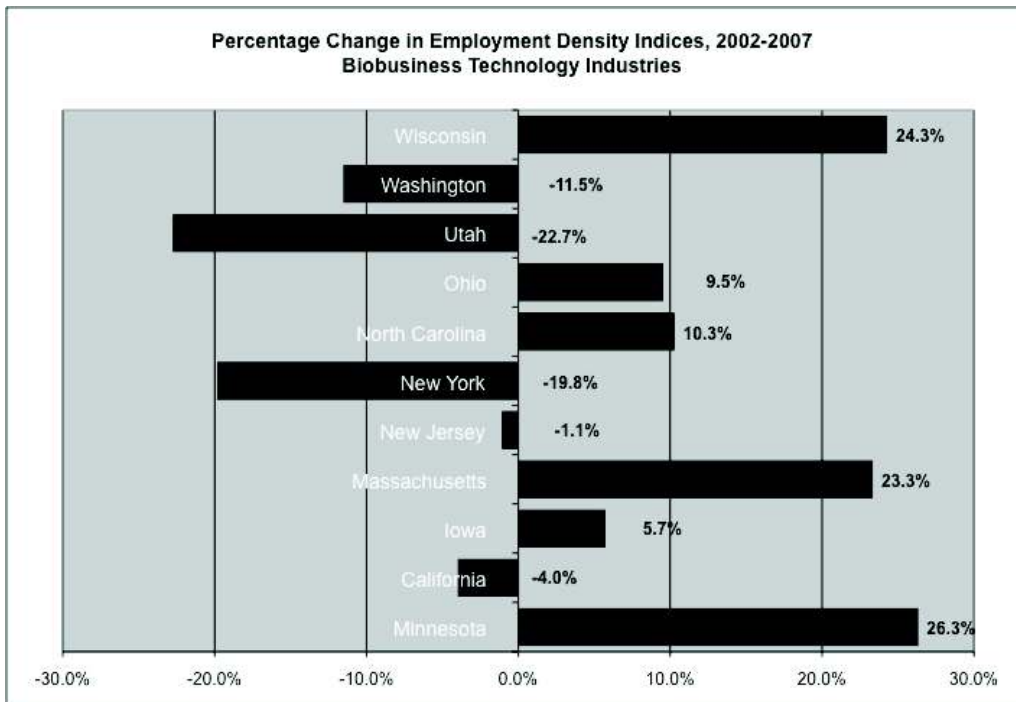


Figure 10B: Percentage Change in Employment Density Indices, 2002-2007, Biobusiness Technology Industries



In the previous Minnesota statewide biobusiness assessment it was argued that Minnesota had sufficient basic strength in biobusiness technology that, if it managed to develop and implement powerful and sophisticated strategies in the near future, it might be able to lift itself from a middling position to one of national prominence in the industry.<sup>18</sup> The positive results portrayed in Figure 9 (reinforced by the positive results portrayed in Figure 8) suggest that that prognosis was correct and that Minnesota has indeed taken appropriate constructive action to capitalize on its underlying strength.

An even more evocative 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. Figures 10A and 10B do this for employment density indices for the eleven states for the five years between 1997 and 2002 and again for the five years between 2002 and 2007. Figures 10A and 10B take the same data that were used to calculate the employment density indices in Figure 8 but express each shift as a percentage change over five years from the base position of each state at the beginning of the respective period.

These two graphs may be useful for helping state leaders 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 the right hand side of each graph are improving their game, while the states positioned on the left hand side of each graph may need to readjust their game plans.

**The most impressive feature of the information in these Figures is the dramatic shift in the position of Minnesota, from that of the “weakest” state to that of the “strongest” state, in terms of its dynamic propensity for generating employment through biobusiness technology.** During the first half of the decade Minnesota was the state that exhibited the largest decline in its competitiveness; but during the second half of the decade Minnesota transformed itself into the state that exhibited the largest increase in its competitiveness. In this regard, it was followed very closely by both Massachusetts and Wisconsin—and these two states will obviously be competitors that Minnesota’s leaders would be wise to watch—but, nevertheless, Minnesota may be justified in raising its hopes about carving out a competitive position for its biobusiness technology sector during coming years.

## 5. Medical Devices

The medical devices sector, as shown by Figure 3, is the most prominent part of Minnesota’s biobusiness industry; and its prominence has increased since the last statewide assessment was conducted. It is therefore important to look at the competitiveness of this sector in its own right.

Figure 11 compares Minnesota with ten other U.S. states in medical devices industry employment at three points in time, 1997, 2002 and 2007. Minnesota is second only to California in the number of medical devices jobs to which the state is home. Additionally, while most of the other competitor states (including California) lost medical devices jobs during the second half of the decade, the number of jobs in Minnesota in this

<sup>18</sup> *Biobusiness* (2006), page 22.



Figure 11: Employment, Medical Devices Industry—1997, 2002 & 2007

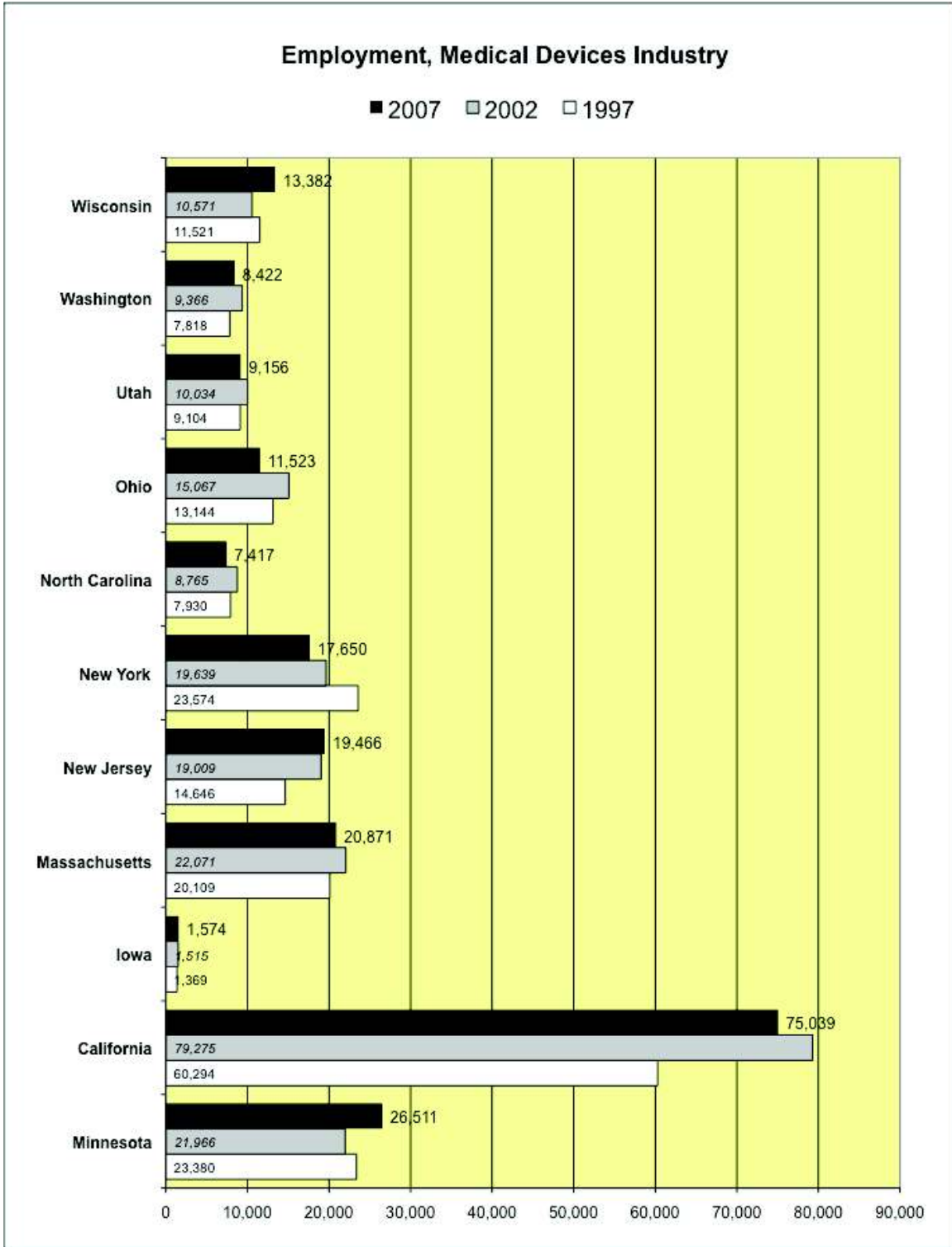
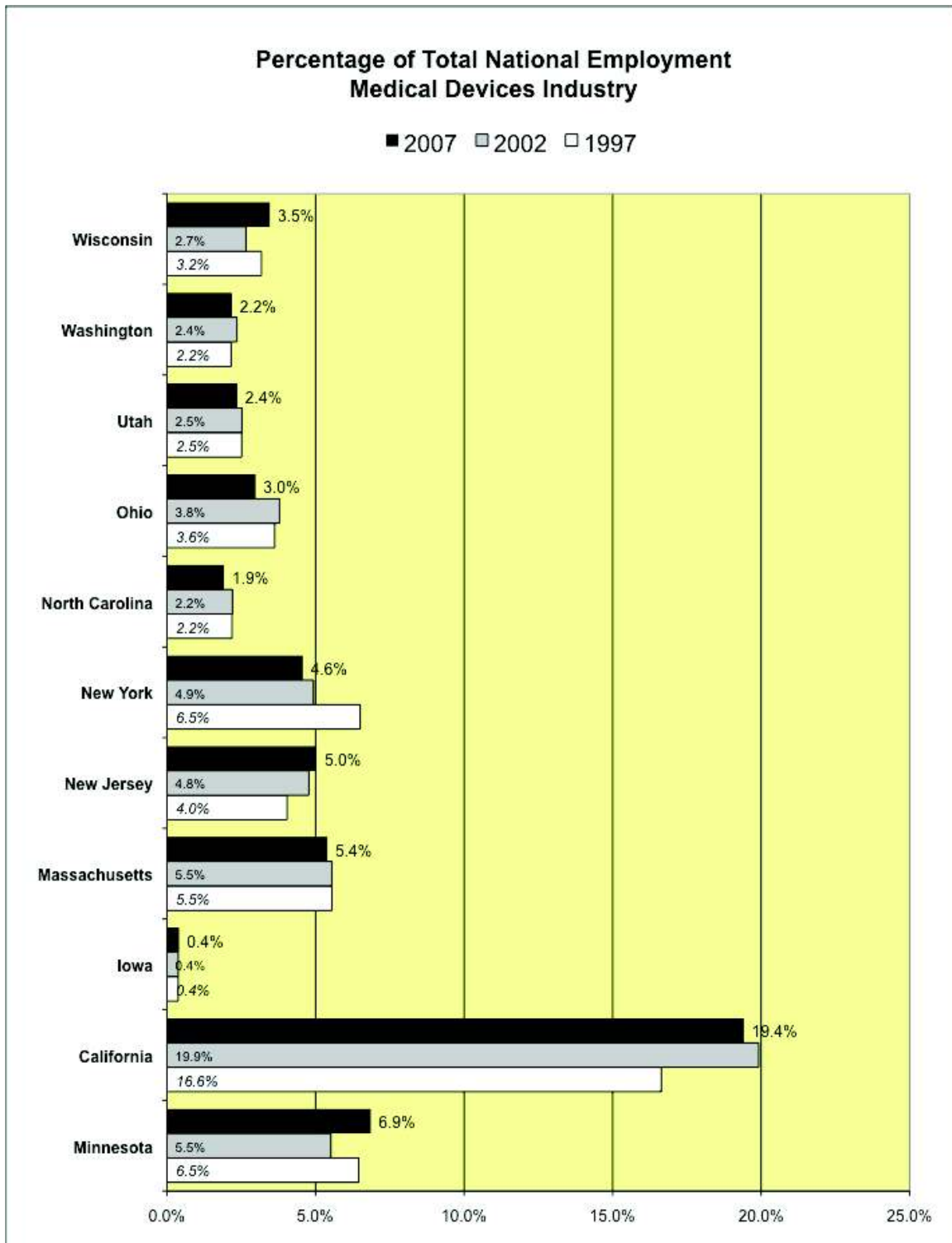


Figure 12: Percentage of Total National Employment in Biobusiness Technology Industries—1997, 2002 & 2007



field actually grew significantly. During that period, while the nation as a whole lost more than 11,000 medical devices jobs in the aggregate, the number of people employed in medical devices enterprises in Minnesota grew by over 4,500 people. This represents a growth rate in Minnesota of over 20 percent. The only other states in our comparison group of eleven states to have gained medical devices jobs during the same period were Wisconsin (with an increase of just over 2,800 jobs), New Jersey (with an increase of just over 450 jobs) and Iowa (with a barely perceptible increase of less than 60 jobs). Minnesota appears to have regained its lost ground as a leading medical devices employer, overshadowed now only by California.

Figure 12 takes the same data that were used to construct Figure 11 but expresses them as percentages of the national total, rather than as absolute employment numbers. The “national total” here refers to the total of the whole of the United States, not just the total of the eleven comparison states that are the focus for our analysis. The general pattern of the results is similar to that which may be observed in Figure 11. This suggests, among other things, that conclusions we may draw from the analysis of Minnesota's competitive position within the group of eleven comparison states included in this study are broadly indicative of Minnesota's dynamic position within the nation.

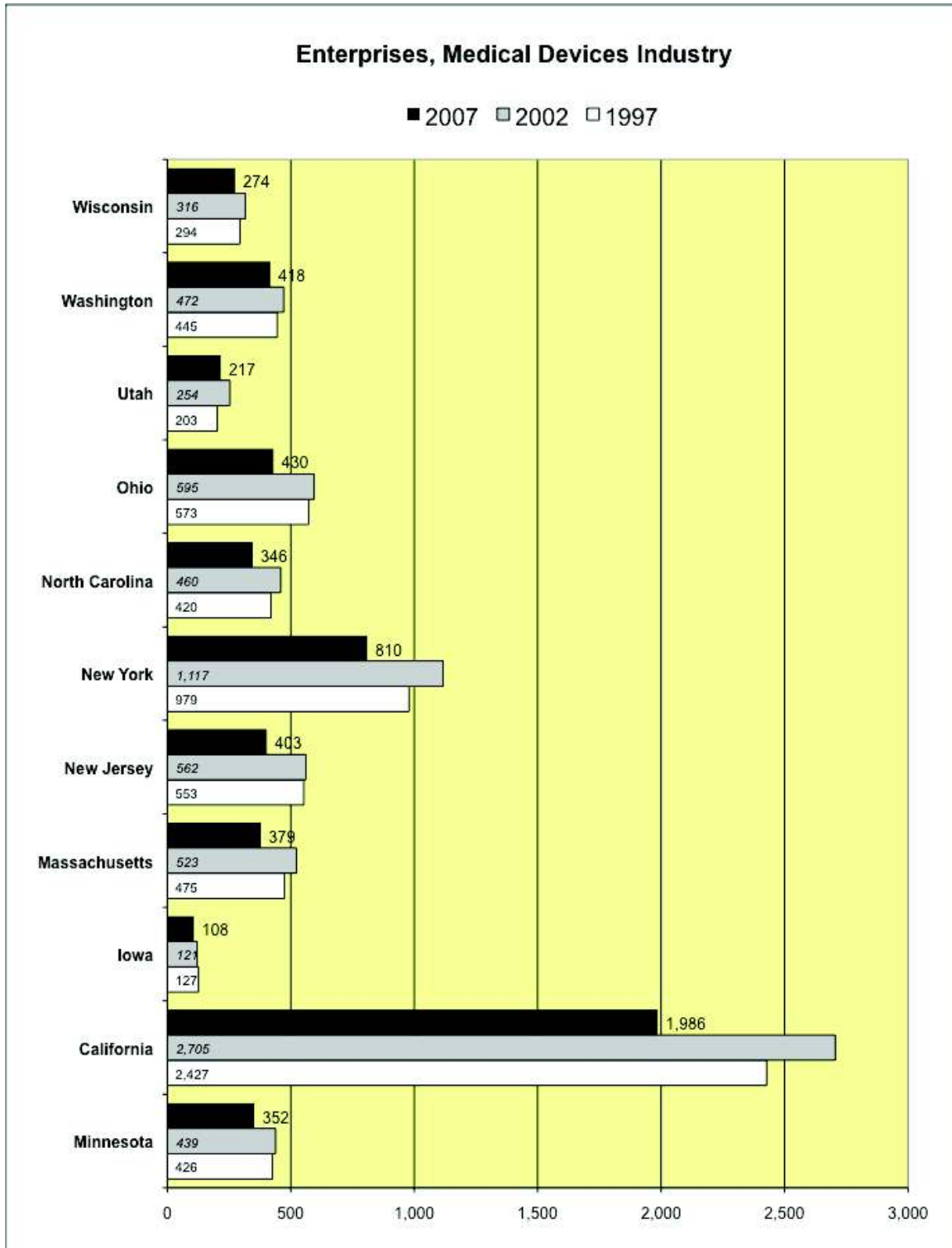
Figure 13 contains similar type of information as Figure 11, except that it compares the number of medical devices enterprises in each of the eleven selected states, rather than the total number of employed persons. Along with all other comparison states, including California, between 2002 and 2007 Minnesota exhibited a reduction in the number of its medical devices enterprises.

As we observed in the case of biobusiness technology enterprises in general (see Figure 7), the general trend observable in Figure 13 suggests that national factors, unrelated to the peculiarities of each state, drove consolidation within the medical devices industry during the period in question. Minnesota, which was obviously caught up in the national trend, experienced a contraction of almost 20% in the number of medical devices enterprises in the state. California, New York, Massachusetts, New Jersey and Ohio, for example, each experienced a contraction in the general range of between 27% and 28 percent. Thus, while Minnesota experienced a contraction in its medical devices enterprise population from 2002 to 2007, the state managed to resist the national trend towards consolidation better than did its significant competitor states.

Once again, it is also important to recall that, while the number of medical devices enterprises dropped, the total number of people employed in medical devices firms in Minnesota actually increased. Thus, the net effect is that there was no economic loss from the consolidation.

The average size of medical devices enterprises in Minnesota increased during the half-decade following 2002 from 50 people to over 75 people per firm (a 51% increase). During the same period the average size of medical devices enterprises in California increased from 29 people to 38 people per firm (a 29% increase). The comparable increase for the biobusiness technology industry as a whole, across the United States (all 50 states), was from 23 people to 30 people per firm (a 28% increase). These numbers suggest that medical devices firms in Minnesota tend to be more mature than is typically the case for those firms in most of the states with which Minnesota competes; and that during the second half of the decade the relative maturity of medical devices firms in Minnesota actually increased.

Figure 13: Enterprises, Medical Devices Industry—1997, 2002 & 2007



The competitor states with the smallest average firm size in 2007 were Iowa (15 people per firm), Washington (20 people per firm), North Carolina (21 people per firm) and New York (22 people per firm). While this feature might be interpreted as a weakness (i.e., lack of maturity in the face of intense national and international competition) it might also be interpreted as a potential source of strength (i.e., a sign of an entrepreneurial business structure, enabling flexibility and innovation in response to competitive pressures). Of these four states, Washington and North Carolina exhibited the lowest growth in mean firm size after 2002, suggesting that these two states are especially attractive for small “entrepreneurial” style firms in the medical devices sector. Nevertheless, as both of these states lost medical devices employment from 2002 to 2007—in contrast with Minnesota, which enjoyed a comfortable gain in employment during that period—it seems unlikely that either state would be a significant competitive threat to Minnesota through entrepreneurship in the medical devices sector in the near future. Washington and North Carolina do not appear to have been able to translate entrepreneurial vigor in to aggregate employment growth in the medical devices industry.

Even New York, which is home to more than double the number of medical devices firms of Minnesota, lost ground during the second half of the decade in both the number of employees and the number of enterprises in the sector. Given that the average size of medical devices firms in New York grew by 24% during the same period, it does not appear that New York is currently succeeding in re-energizing its medical devices industry through entrepreneurship—despite the fact that the state did exhibit some signs of entrepreneurial renewal during the late 1990s. Rather, it appears that New York has continued to undergo a wave of consolidation, contraction and maturation in the medical devices sector and should probably not be seen as a growing competitive threat to Minnesota in the near future. When trends in both employment levels and enterprise populations are taken in to account, it appears that the most serious competitive threats to Minnesota in the medical devices industry in the foreseeable future will come from Massachusetts and New Jersey—in addition, of course, to the ongoing robust competition from California.

The fact that California has many more medical devices jobs and firms than Minnesota, and that a number of other states have populations of medical devices firms larger than Minnesota's (and also have medical device employment levels beginning to approach that of Minnesota) is not in itself a cause for concern. These states have 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 14 was produced to put these factors in to perspective, by expressing each state's medical devices employment position as an employment density index rather than as an absolute number of jobs.

According to Figure 14, Minnesota, Utah, Massachusetts, California, Wisconsin, New Jersey and Washington are “competitive.” The main message to be extracted from the results in Figure 14, however, is that **Minnesota is the most competitive of the eleven states in generating employment in the medical devices industry.** With an employment density index for medical devices of 3.3, Minnesota's competitiveness (i.e., its productivity in generating employment in the medical devices industry, taking in to account the relative size of Minnesota's economy, the size of the national economy and the aggregate size of the medical devices industry throughout the nation) is roughly

Figure 14: Employment Density Indices, Medical Devices Industry—1997, 2002 & 2007

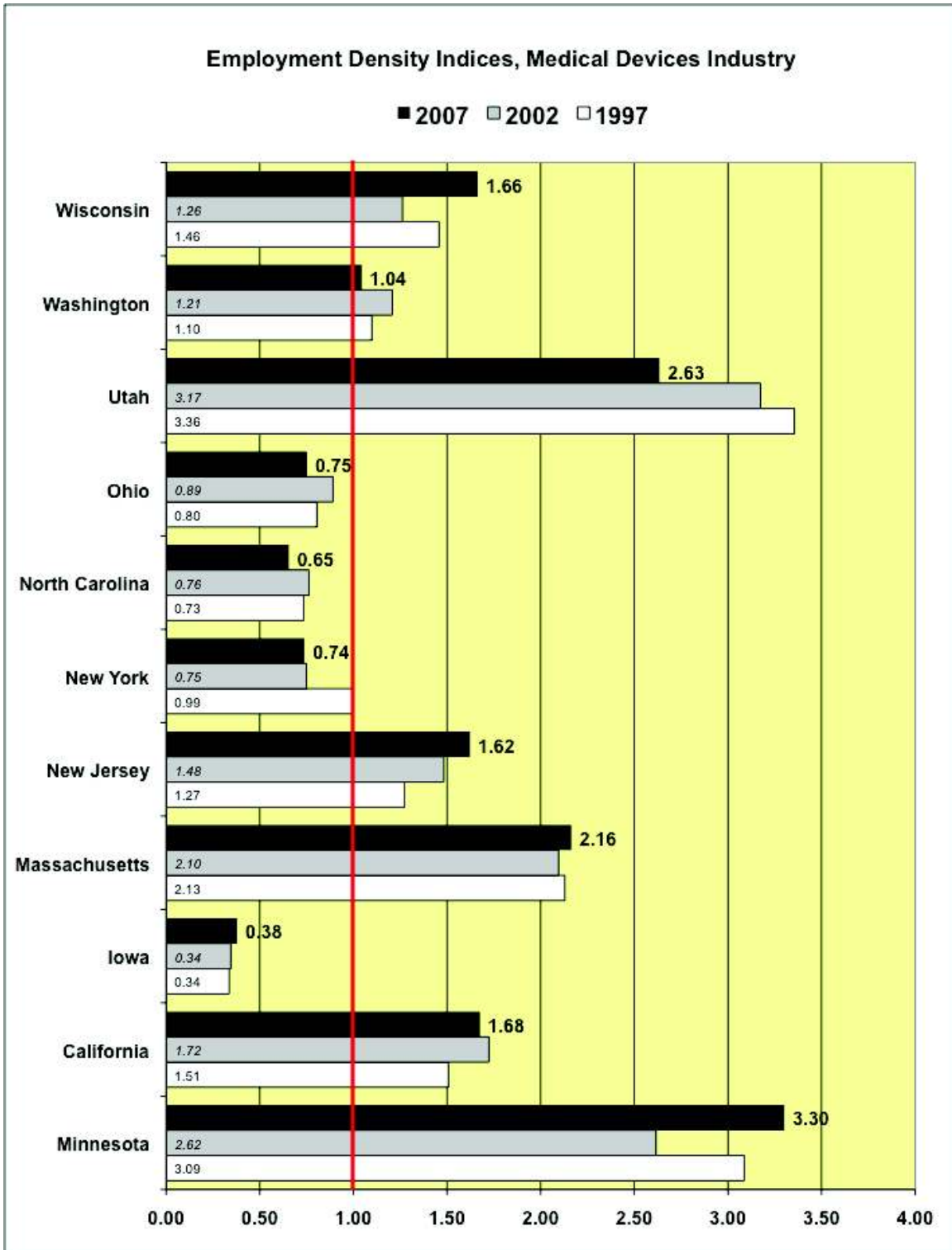
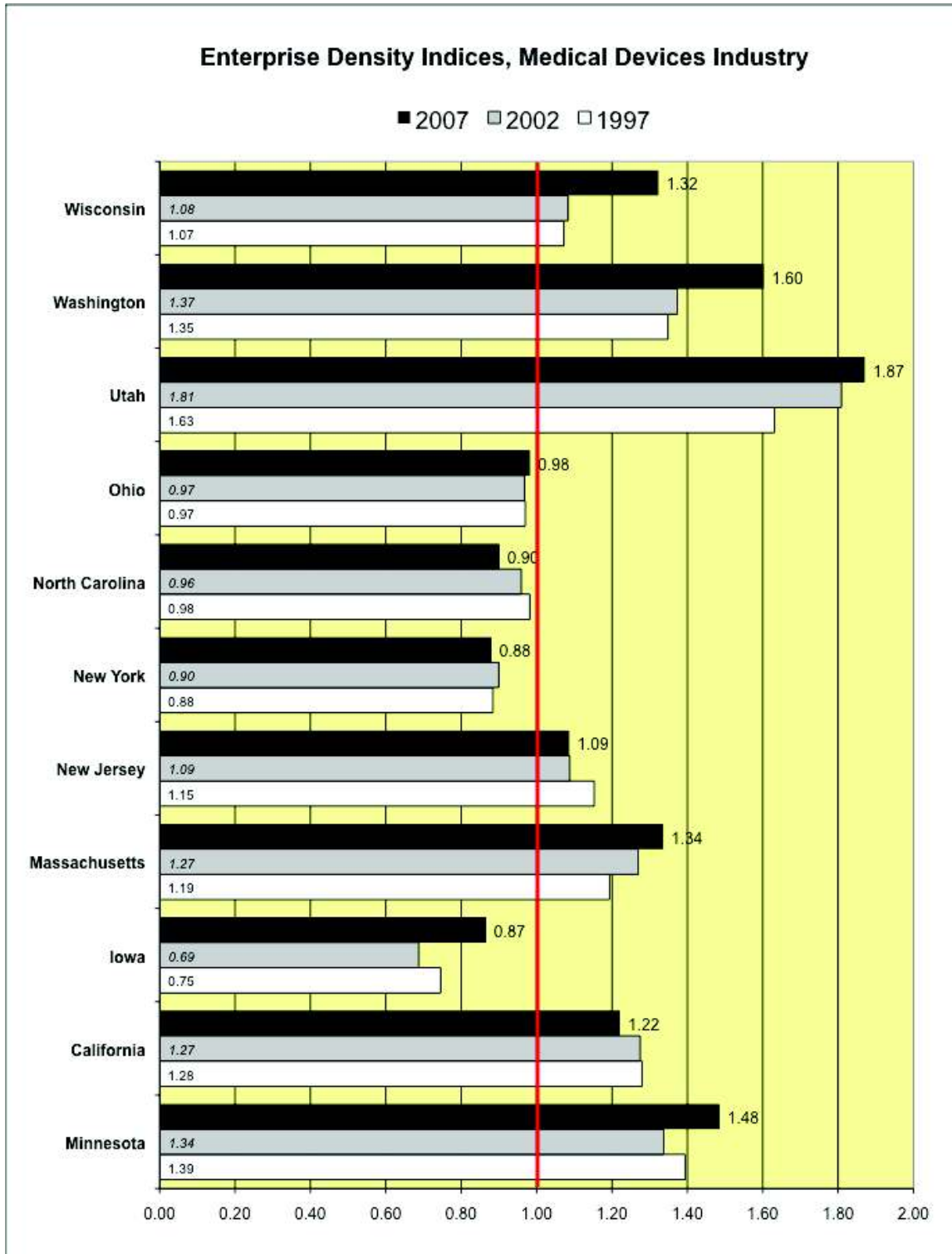




Figure 15: Enterprise Density Indices, Medical Devices Industry—1997, 2002 & 2007



double that of California; and its lead over California increased during the second half of the decade.

Figure 14 also reveals that the two states suggested by Figure 13 as the most likely serious competitive threats to Minnesota in the medical devices industry in the foreseeable future—Massachusetts and New Jersey—also, and not surprisingly, exhibit unusually high employment density indices. The accomplishments of these two states in regards to medical devices appear to derive from their underlying competitiveness in the industry rather than from any relative advantages associated with the overall size of their economies. New Jersey in particular is an interesting state to watch: its employment density index for the medical devices industry has continued to rise throughout the decade. Massachusetts, on the other hand, while actually more competitive than New Jersey and highly competitive at a national level (measured according to its respective employment density index), has remained somewhat steady (in both its employment level and its employment density index).

Utah appears to be the outlier here. Utah is the second most competitive state (with Minnesota being first), according to its employment density index. In principle this might make Utah a plausible rival to Minnesota. In 2002 Utah's employment density index for medical devices was actually significantly higher than that of Minnesota, lending real credibility to the notion that Utah might become a serious competitor to Minnesota. However, the fact that Utah's medical devices employment level has failed to increase above its 1997 base, and that Utah's employment density index fell after 1997 and then again after 2002, suggests that Minnesota's competitive advantage over Utah in medical devices employment is sustainable.

Figure 15 plots the enterprise density indices for the medical devices industry in Minnesota and each of its ten selected competitor states. This index is calculated in the same way as the index plotted in Figure 14 except that the base variable is the number of medical devices enterprises rather than the number of medical devices employees. Figure 15 shows that, in descending order of efficiency in creating medical devices firms (given the relative sizes of their respective economies), Utah, Washington, Minnesota, Massachusetts, Wisconsin, California and New Jersey are the “competitive” states—with Ohio remaining stable, just below the cusp.

Minnesota is one of several states whose competitive position improved during the second half of the decade. This is a good sign for Minnesota because it indicates that not only did the state expand its medical devices industry following 2002, to regain the number two position behind California (Figure 11), and not only did it improve its relative efficiency in generating medical devices jobs (Figure 14), it also enhanced its relative prowess as a location for entrepreneurship in medical devices. **Minnesota appears to be strengthening in regards to both its overall growth and maturity in the medical devices industry and its vitality in creating new enterprises.** This is an encouraging change in direction from the pre-2002 situation.

Nevertheless, these encouraging developments in Minnesota's medical devices industry provide no grounds for complacency. Massachusetts has also improved its entrepreneurial effectiveness in medical devices between 2002 and 2007 and New Jersey, while showing no post-2002 increase in its enterprise density index, remained stable in its above-average competitiveness in generating new medical devices firms. Washington and Wisconsin both also exhibited appreciable improvements in their enterprise density

Figure 16A: Percentage Change in Employment Density Indices, 1997-2002, Medical Devices Industry

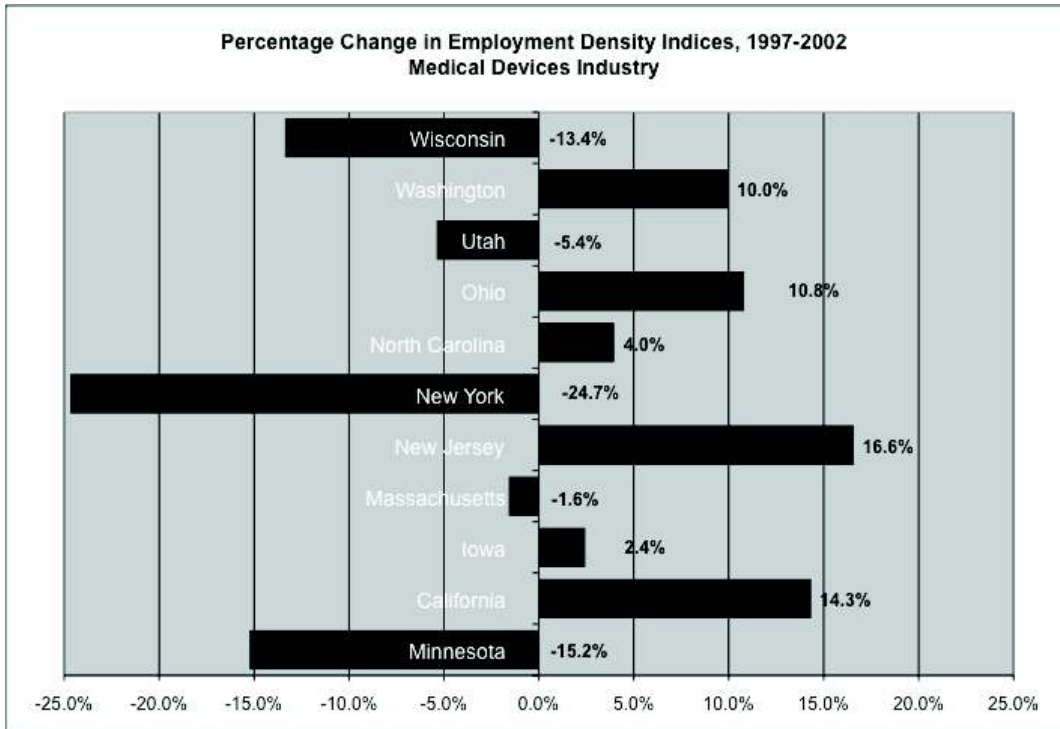
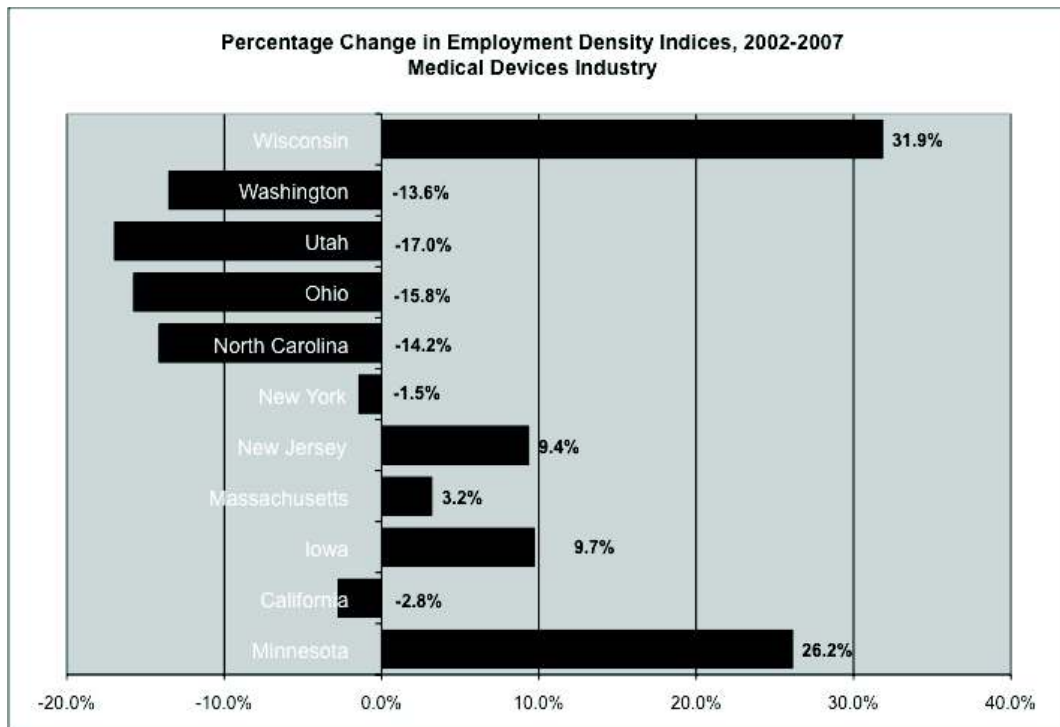


Figure 16B: Percentage Change in Employment Density Indices, 2002-2007, Medical Devices Industry



indices during the second half of the decade. While both of these two states are homes to a significantly smaller number of medical devices jobs than Minnesota, they are both credible competitors to Minnesota as congenial homes for new medical technology enterprises, and the improved relative positions of these states during recent years means that they should not be ignored. Figure 15, when taken together with Figures 11, 12, 13 and 14, reveals that—over and above the ever-present shadow of California—Massachusetts, New Jersey, Washington and Wisconsin are plausible competitors with Minnesota in medical devices entrepreneurship. Despite its recent doldrums in the creation of medical devices jobs and firms, Utah is nevertheless still in the game.

As an aid to mapping shifts in the relative prowess of each state in addressing challenges in their respective local medical devices industries over time, Figures 16A and 16B plot changes in the employment density indices of the eleven competitor states during the first half of the decade and again during the second half of the decade leading up to the date of the most recent U.S. Economic Census. Figures 16A and 16B take the same data that were used to calculate the employment density indices in Figure 14 but express each change as a percentage change over five years from the base position of each state at the beginning of the respective period.

The two high performers during the second half of the decade—*vis-à-vis* improving their game in generating employment in the medical devices industry—are Wisconsin and Minnesota. For both of these states, their accomplishment represents a dramatic turnaround from their performance during the first half of the decade. Massachusetts, although more modest in the relative scale of its accomplishments, nevertheless also achieved a turnaround from the first half of the decade to the second. New Jersey and Iowa both maintained their strong performance throughout the decade.

In summary, overall, since 2002, Minnesota has enjoyed an encouraging positive turnaround in its competitive position in the medical devices industry. By the end of the decade it was second only to California in the number of medical devices jobs and it moved in to the top position (above California) in terms of its productivity as a state in generating medical devices employment, taking in to account the relative size of its economy and the state of the industry and the general economy nationwide. Despite significant (and improving) competition from a number of other states, Minnesota managed to regain and build upon its competitive position in the medical devices industry.

## 6. R&D in the Life Sciences

“R&D in the life sciences” is the overarching label employed here for research and development in biotechnology and research and development in other biology-related fields. During the last three decades a new set of industries in this domain, 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. The data reported here cover only business organizations in this domain, and exclude life sciences research in government institutes, universities and various other not-for-profit academic organizations. Figure 17, using data taken from the U.S. Economic Census, graphs employment levels in this new industry across the same eleven states and the same three points in time that were reviewed above

Figure 17: Employment, R&D in the Life Sciences—1997, 2002 & 2007

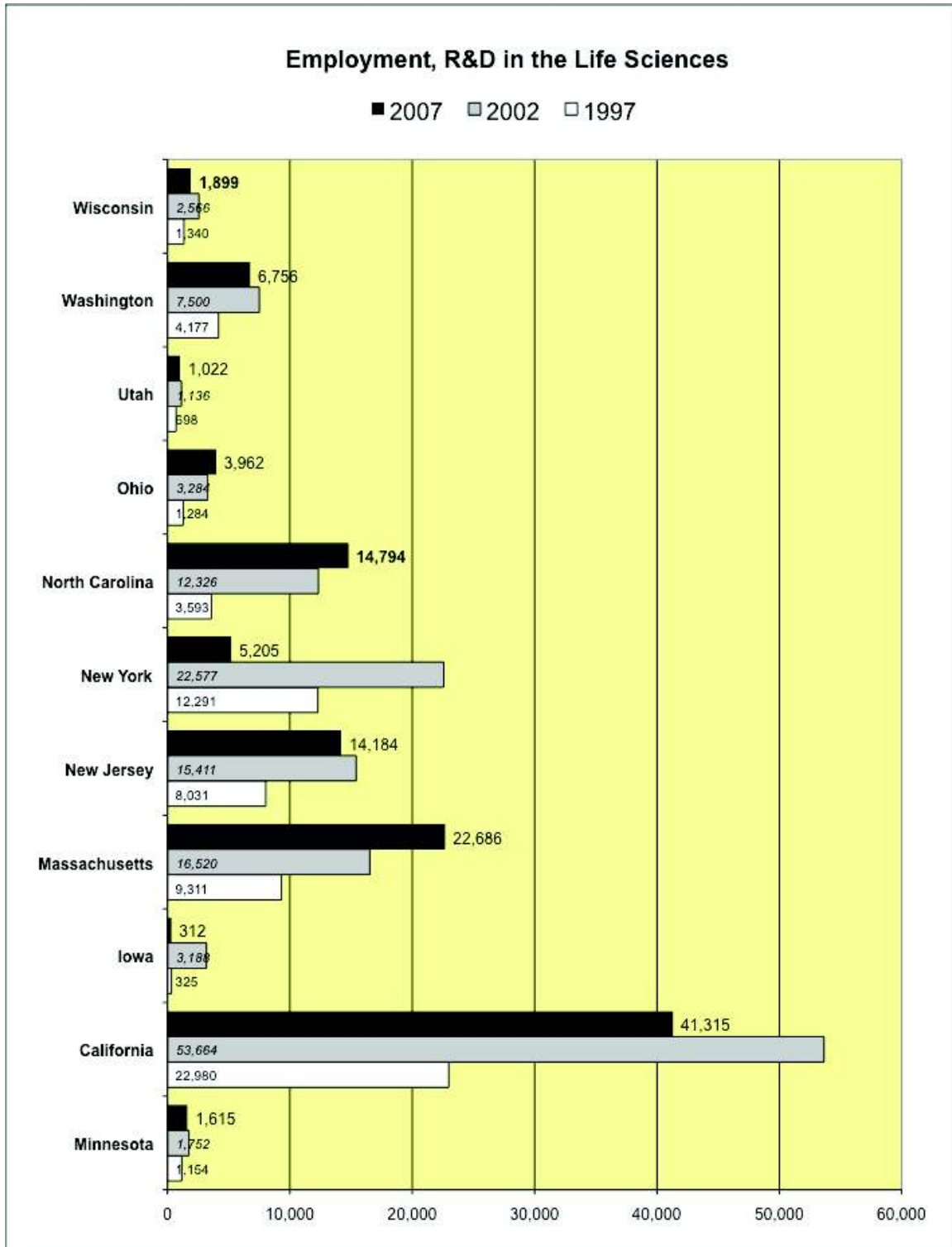
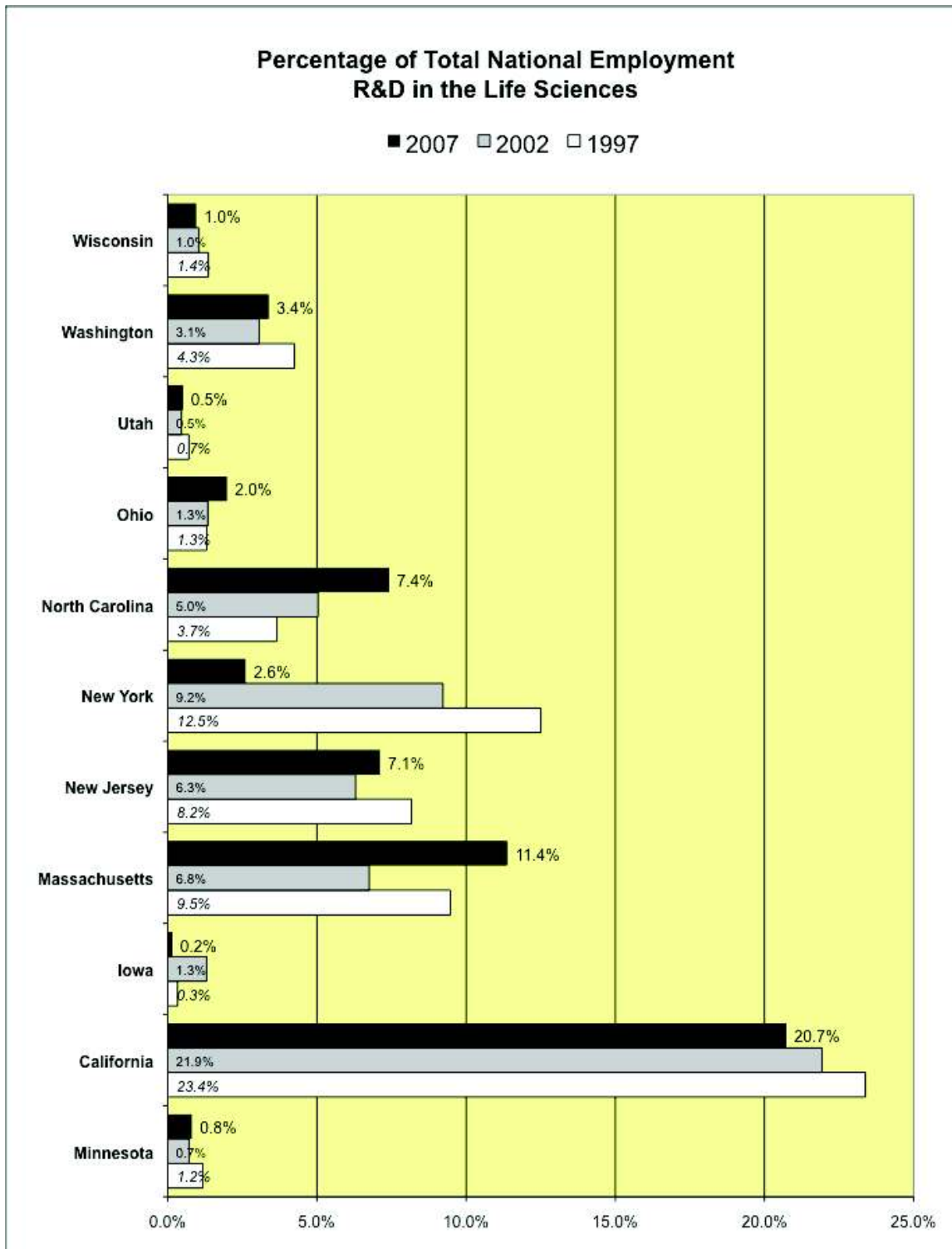


Figure 18: Percentage of Total National Employment, R&D in the Life Sciences—1997, 2002 & 2007





for the medical devices industry. Figure 18 takes the same data that were used to construct Figure 17 but expresses them as percentages of the national total (i.e., the total for the United States as a whole, not just the total for the eleven comparison states), rather than as absolute employment numbers.

In contrast with its historical leadership role in the medical devices industry, Minnesota is not a leading employer in the new life sciences R&D industries. At the end of 2007, as was the case during 2002, only Iowa and Utah among the eleven comparison states exhibited smaller absolute employment levels than Minnesota in R&D in the life sciences. By the end of 2007, as shown by Figure 18, Minnesota's share of total national employment in the life sciences R&D industries had nevertheless improved slightly, while Utah's remained stable and Iowa's slipped.

California, as we have seen with both medical devices and biobusiness technology in general, remains the overwhelming leader in life-sciences R&D employment. Nevertheless, California failed to maintain the stunning growth it exhibited during the first half of the decade. During the second half of the decade California lost almost 12,000 jobs in this area and reduced its share of national employment by 1.2% to 20.7 percent.

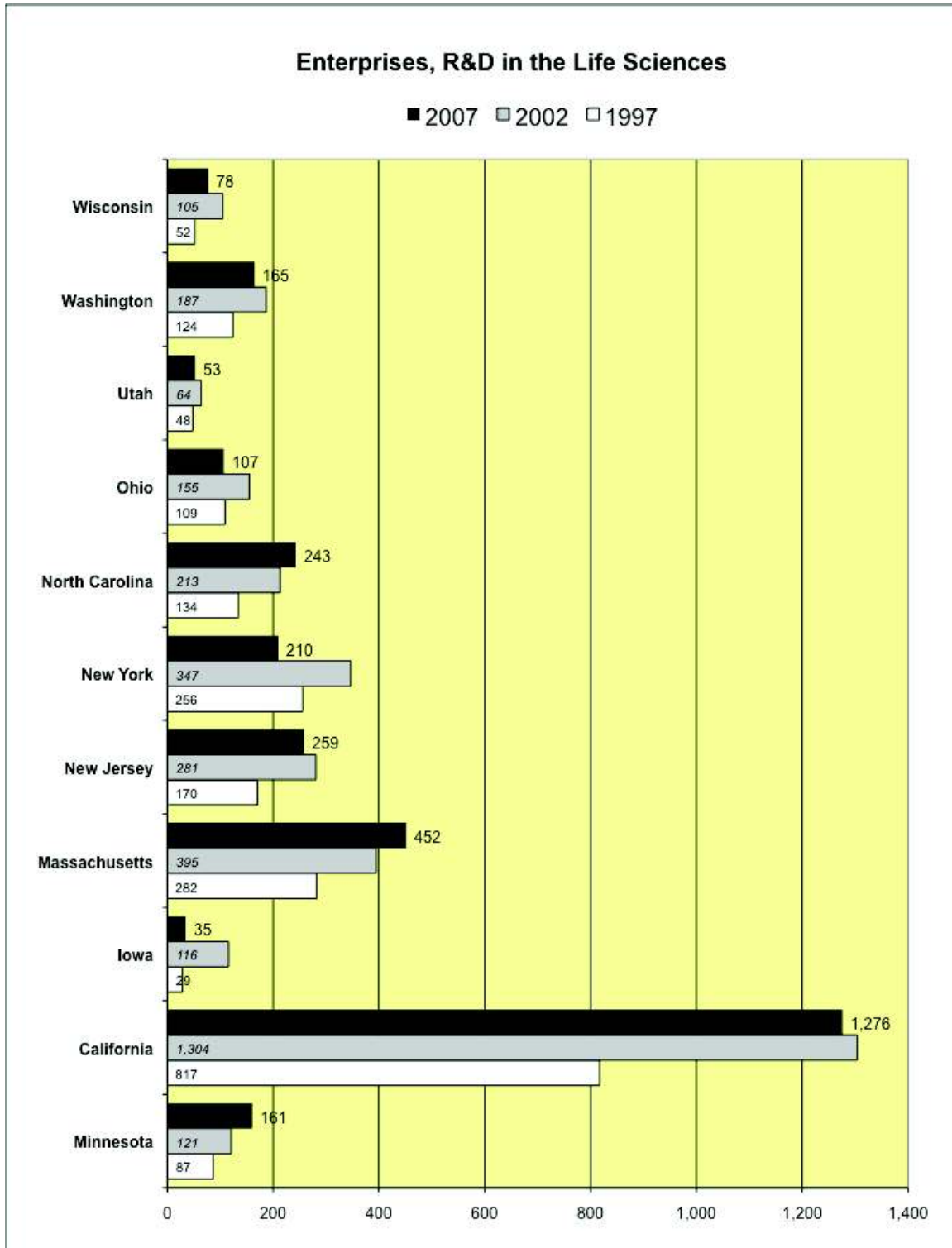
The big story to be gleaned from the data in these two figures is the impressive, if not dramatic, rise of both Massachusetts and North Carolina. At the end of 2002 life sciences R&D employment in North Carolina was 23% of that of California, but five years later it had risen to 36% of the level of the leading state. Employment in life sciences R&D in Massachusetts rose during the same time period from 31% to 55% of the level of employment in life sciences R&D in California. There appears to be some significant inter-state realignment going on in the United States in the area of commercial life sciences R&D.

The report of the results of Minnesota's previous statewide biobusiness assessment (conducted five years ago) contained the following observation: "Minnesota is growing more slowly than the nation as a whole in 'R&D in the life sciences' employment."<sup>19</sup> At that time the United States as a whole had enjoyed a growth of 149% in life sciences R&D employment during the previous half-decade whereas Minnesota's employment in the field had grown by only 52 percent. Since then, however, the situation has changed. During the half-decade following the previous Economic Census, total life sciences R&D employment in the United States dropped by about 19% and many states experienced painful drops much larger than that (e.g., New York experienced a 77% reduction). California experienced a reduction of 23 percent, following its previous rise of 134 percent. Minnesota managed to contain its reduction after 2002 to 8% only. In other words, Minnesota reversed its situation from being significantly below the national average prior to 2002, to being significantly above the national average after 2002, *vis-à-vis* employment growth in life sciences R&D.

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 in this particular field of industry. Figure 19 was produced for this purpose. Figure 19 reveals that Minnesota fairs slightly

<sup>19</sup> *Biobusiness* (2006), page 32.

Figure 19: Enterprises, R&D in the Life Sciences—1997, 2002 & 2007



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.

Nevertheless, Figure 19 reveals that Minnesota has continued to improve. During the second half of the decade the United States as a whole experienced a net loss of 7% of life sciences R&D enterprises, whereas Minnesota managed to achieve a net gain of 33 percent. In fact, Minnesota was one of only three of the eleven comparison states to experience a net gain in the number of life sciences R&D firms after 2002. The other two, Massachusetts and North Carolina, both grew new enterprises at less than half the rate of Minnesota. While the absolute scale of life sciences entrepreneurship in Massachusetts (52 new firms, net) was greater than that of Minnesota (40 new firms, net), Minnesota's rate of entrepreneurship in the field was the highest.

We should not exaggerate the relative strength of Minnesota in generating life sciences R&D firms. After all, the state still lags behind New York, North Carolina and New Jersey in the number of its life sciences R&D firms; and of course it lags significantly behind both Massachusetts and California in this regard. In terms of life sciences R&D employment, we should remember that Minnesota is an even smaller player than Wisconsin. Nevertheless, despite being a minor player in the field, Minnesota has revealed its resilience as a location for entrepreneurship in life sciences R&D. For example, by the end of the decade Minnesota was home to almost as many life sciences R&D firms as the state of Washington ... a place that is world renowned for this industry.

Figure 20 and 21 enable us to weight the results from Figures 17 and 19 to take in to account the relative sizes of each of the eleven states *vis-à-vis* each other's economies and the national economy together with the size of the life sciences R&D industry nationwide. Figure 20 plots employment density indices and Figure 21 plots enterprise density indices for all eleven states for R&D in the life sciences.

The "competitive" states in the generation of employment in life sciences R&D, according to Figure 20, in descending order are: Massachusetts, North Carolina, New Jersey, California and Washington. We could say, informally, that these five states exhibit high "entrepreneurship quotients" for life sciences R&D. Minnesota, with an employment density index of just 0.39, is near the bottom of the list. Massachusetts (with an employment density index of 4.56) leads the pack by a long margin in its productivity in generating new employment in life sciences R&D. Figure 20 also reveals that the recent dramatic growth of both Massachusetts and North Carolina as locations for life sciences R&D employment (see Figure 17) stems not from the relative size of their populations or economies but from their underlying competitiveness in the field.

Massachusetts, according to Figure 21, also leads the pack by a long margin in its productivity in generating life sciences R&D enterprises (i.e., in what most commentators would call "biotech entrepreneurship"). Even though California was home to almost three times as many life sciences R&D enterprises at the end of 2008 as Massachusetts, Massachusetts' enterprise density index for this field (at 3.64) was more than double that of California (at 1.80). Thus, Massachusetts is significantly stronger than California in life sciences R&D entrepreneurship, despite having a much smaller population and economy.

Figure 20: Employment Density Indices, R&D in the Life Sciences—1997, 2002 & 2007

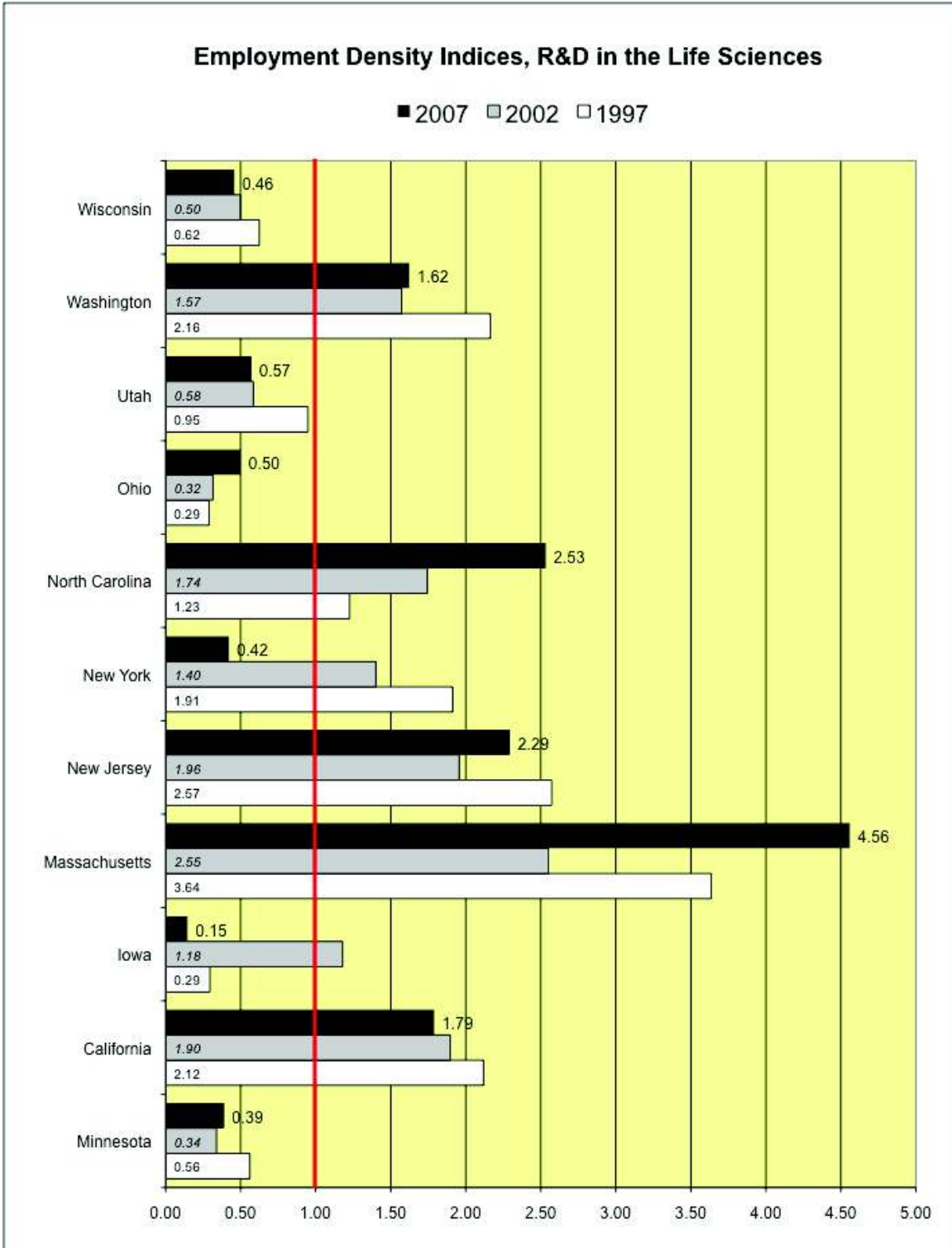


Figure 21: Enterprise Density Indices, R&D in the Life Sciences—1997, 2002 & 2007

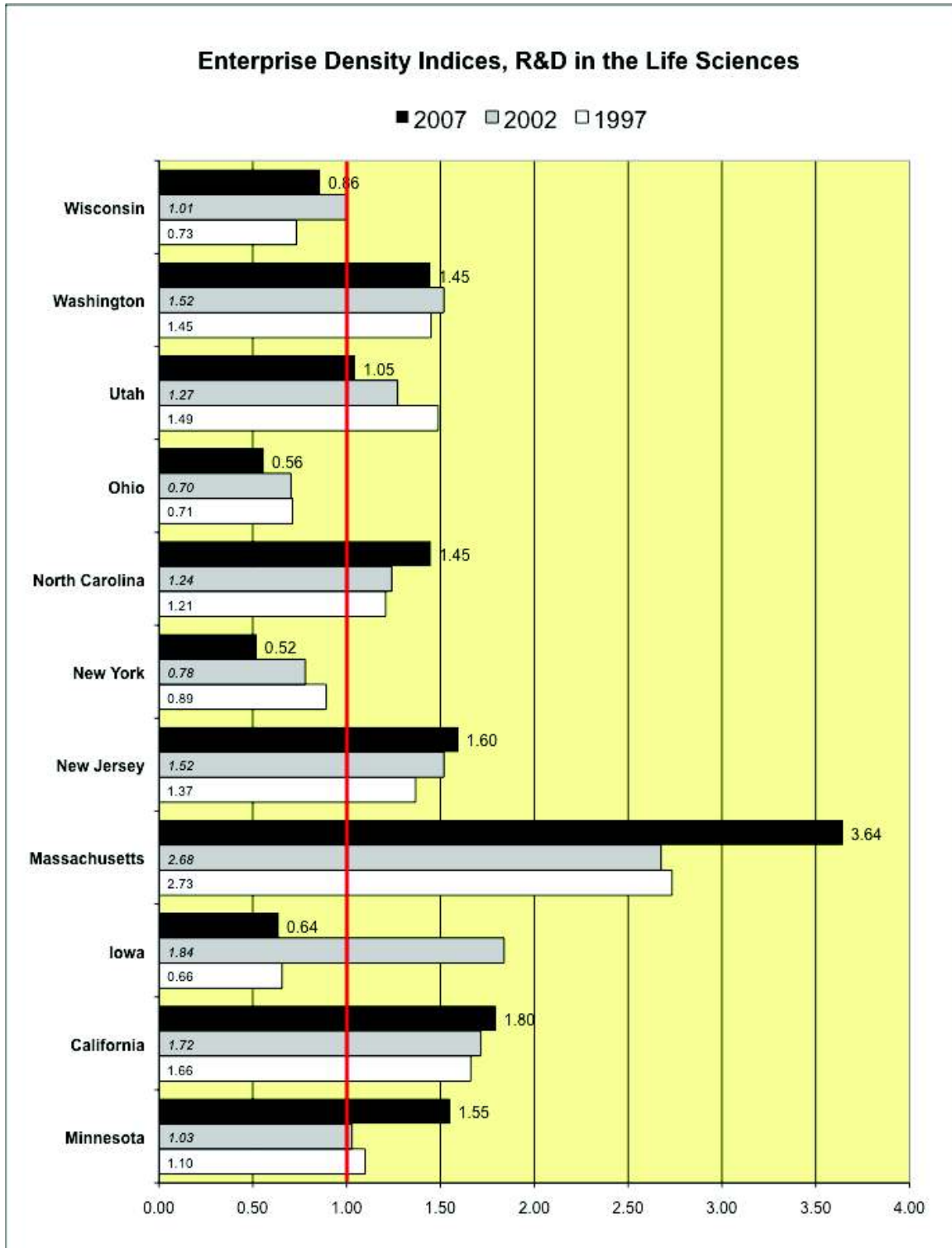


Figure 21 also contains some especially interesting information for Minnesota. Minnesota has remained “competitive” as a place for entrepreneurship in life sciences R&D (i.e., its enterprise density index has remained above 1.0) throughout the previous decade; but it has also improved its performance considerably during the second half of the decade. By the end of 2007 Minnesota had surpassed North Carolina, Washington and Utah, reversing the situation of the previous period during which its enterprise density index was lower than the indices of those three states. Minnesota’s relatively strong enterprise density index (at 1.55) suggests that, while it will most likely never become a major national player in the life sciences R&D industry, the industry will continue to play a positive role in the state and, more likely than not, will grow during coming years.

As we saw in the case of the medical devices industry, and the biobusiness technology industries in general, 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 aggregate performance in the short term. Careful analysis of these indicators can provide a kind of early warning system of either impending “sleeper” problems or even of unexpected future success, as the case may be. Figure 22A and Figure 22B were designed to play that role for the life sciences R&D industry.

The most impressive insight that may be drawn from Figures 22A and 22B is that Minnesota shifted from the position of being the weakest performer of the eleven states during the first half of the decade to being among the top three by the second half of the decade. Minnesota has apparently been doing something right during recent years, not just in the medical devices area, but also in the business of life sciences R&D.

Massachusetts and Wisconsin are the two outstanding states in terms of dynamic performance, with each exhibiting an upward swing of about 23% in their employment density indices during the second half of the decade for R&D in the life sciences. Massachusetts moved from neutral to positive during that period, signaling that state’s improvement upon its already strong base. Wisconsin moved from negative to positive, signaling that it will be a state to watch in coming years. While North Carolina’s upward swing was only about 6% compared with its earlier upward swing of about 26% we should not conclude that its position has weakened. To the contrary, its situation has continued to improve, as demonstrated by its growth in both employment (Figure 17) and enterprises (Figure 19) in life sciences R&D after 2002. Rather, the big change here is that Massachusetts, Wisconsin and Minnesota have all lifted their game, thereby signaling greater competition for North Carolina in future years.



Figure 22A: Percentage Change in Employment Density Indices, 1997-2002, R&D in the Life Sciences

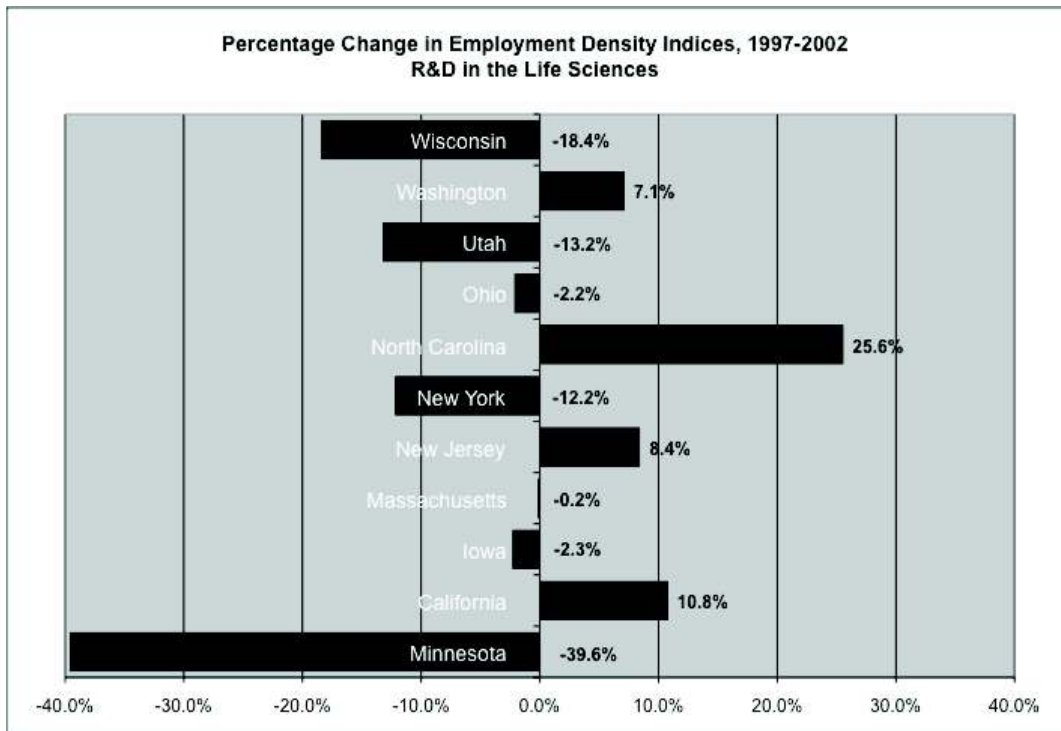
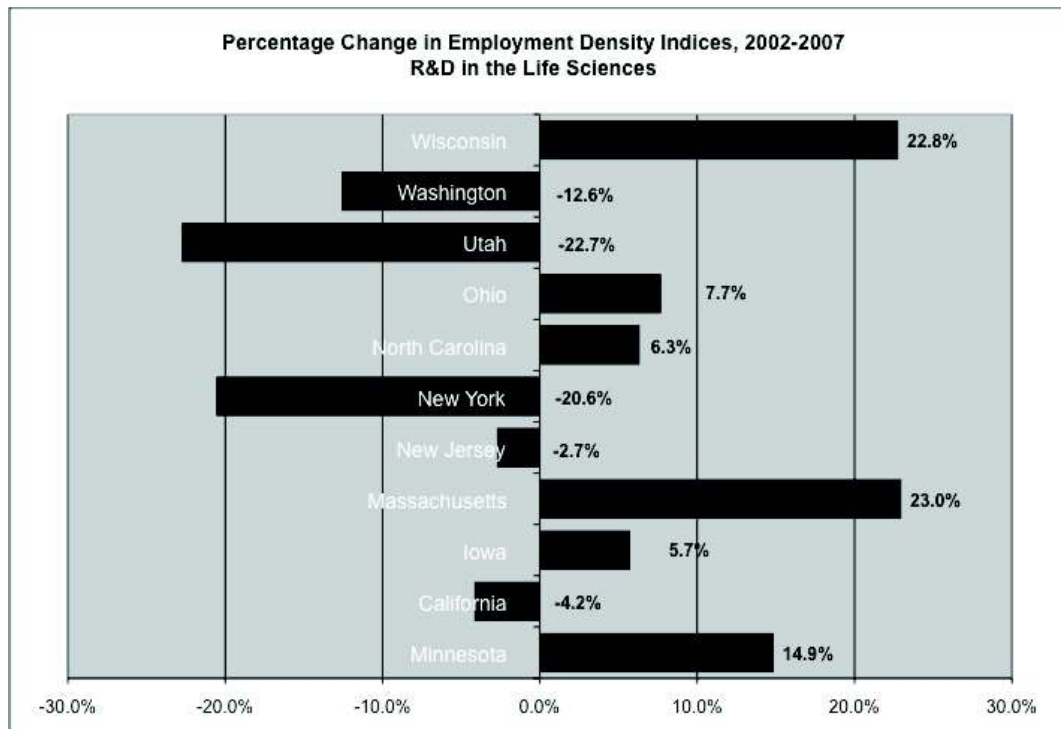


Figure 22B: Percentage Change in Employment Density Indices, 2002-2007, R&D in the Life Sciences



## 7. Agri-bio and Bio-industrial Technology

*Agri-bio and bio-industrial technology is technology directed primarily towards applications in biological systems exterior the human body.* It may incorporate technical means from any field of technology, including biotechnology, but it must be directed towards applications in living systems or biology-related contexts. Agri-bio technology may also be thought of as “green biobusiness technology” (focused on the application of biological technology in the field of plants and agriculture) and bio-industrial technology may be thought of as “white biobusiness technology” (focused on the application of biological technology in industrial fields such as bio-materials, bio-processing, bio-energy, bio-based chemicals, food ingredients, and bio-remediation).

There is no standard industrial classification for this general domain of biobusiness so, as explained earlier, the following NAICS categories in combination have been selected as rough proxies for agri-bio and bio-industrial technology: ethyl alcohol manufacturing (NAICS 325193), cellulose organic fiber manufacturing (NAICS 325221), wet corn milling (NAICS 311221), soybean processing (NAICS 311222), other oilseed processing (NAICS 311223), breweries (NAICS 31212) and wineries (NAICS 31213). These are all manufacturing categories, rather than R&D categories, even though many of the manufacturing enterprises captured under these NAICS codes may in fact also engage in R&D activities. Agri-bio and bio-industrial technology firms that focus on R&D activities have not been excluded from this study; rather, they have been included within the general category of R&D in the life sciences, rather than as part of the agri-bio and bio-industrial technology category. *It is also important to recognize that in this report the term “agri-bio and bio-industrial technology” does not include most activities that conventionally belong to agriculture and the food industry.* These are addressed separately under the category “bio production and processing industries” in Appendix 5.

The reliability of the data published on agri-bio and bio-industrial technology as part of the U.S. Economic Census tends not to be as high as for other fields of biobusiness technology, such as medical devices. The primary reason for this is that in cases when there are few facilities within a particular NAICS category within a particular region, the U.S. Census Bureau withholds the data so as to ensure anonymity for individual enterprises. For example, the Census Bureau identified no enterprises within Utah under the relevant NAICS classifications at any of the three pertinent points in time whereas, in fact, Utah is well known to have been the home of at least several breweries and wineries throughout the decade in question. Another possible reason may be that production activities associated with, for example, anaerobic digestion, may occur as a secondary business in the food sector and would be located under the umbrella of grain milling; and thus might not be clearly visible under the “industry microscope” of federal government statisticians. The results presented below, for agri-bio and bio-industrial technology, must therefore be treated with caution.

Nevertheless, the weaknesses in the official data appear primarily in the states that, in any case, contain very small numbers of enterprises engaged primarily in business within the relevant NAICS classifications; thus, the omission of a small number of firms from the data set will have only marginal impact at the aggregate level (for all eleven states and for the nation as a whole) and virtually no impact on the states that are homes

Figure 23: Employment, Agri-bio & Bio-industrial Industries—1997, 2002 & 2007

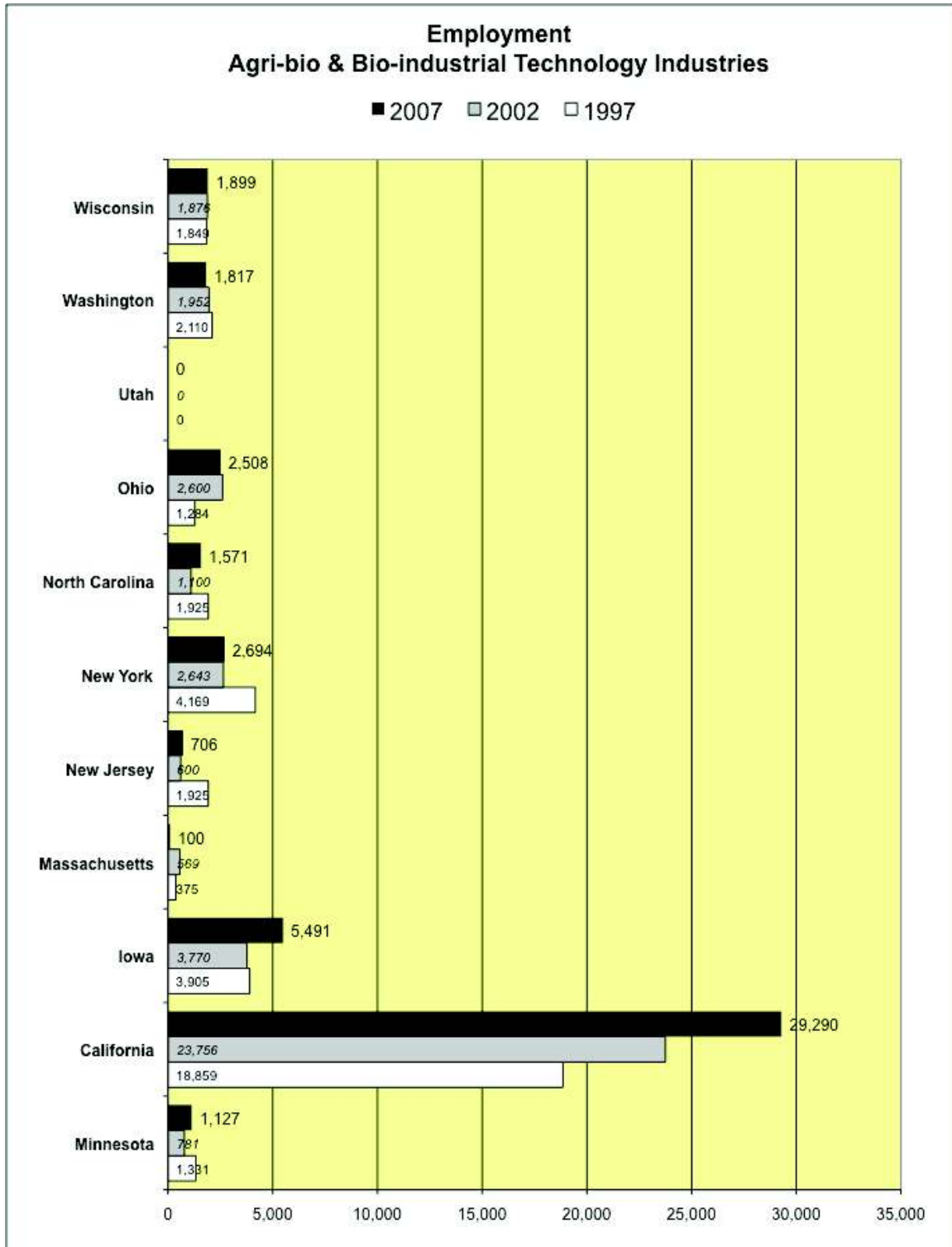
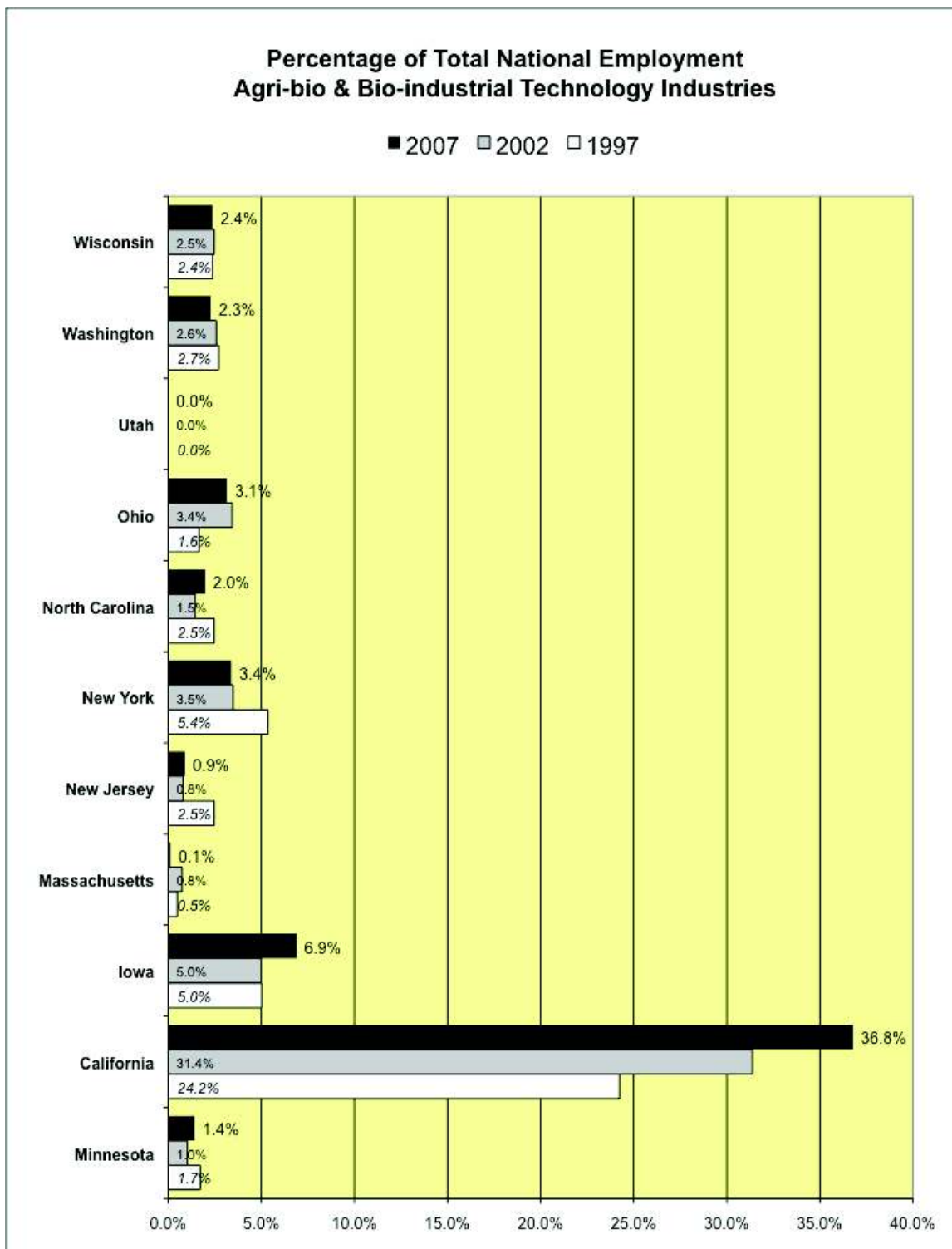


Figure 24: Percentage of Total National Employment in Agri-bio & Bio-industrial Industries—1997, 2002 & 2007



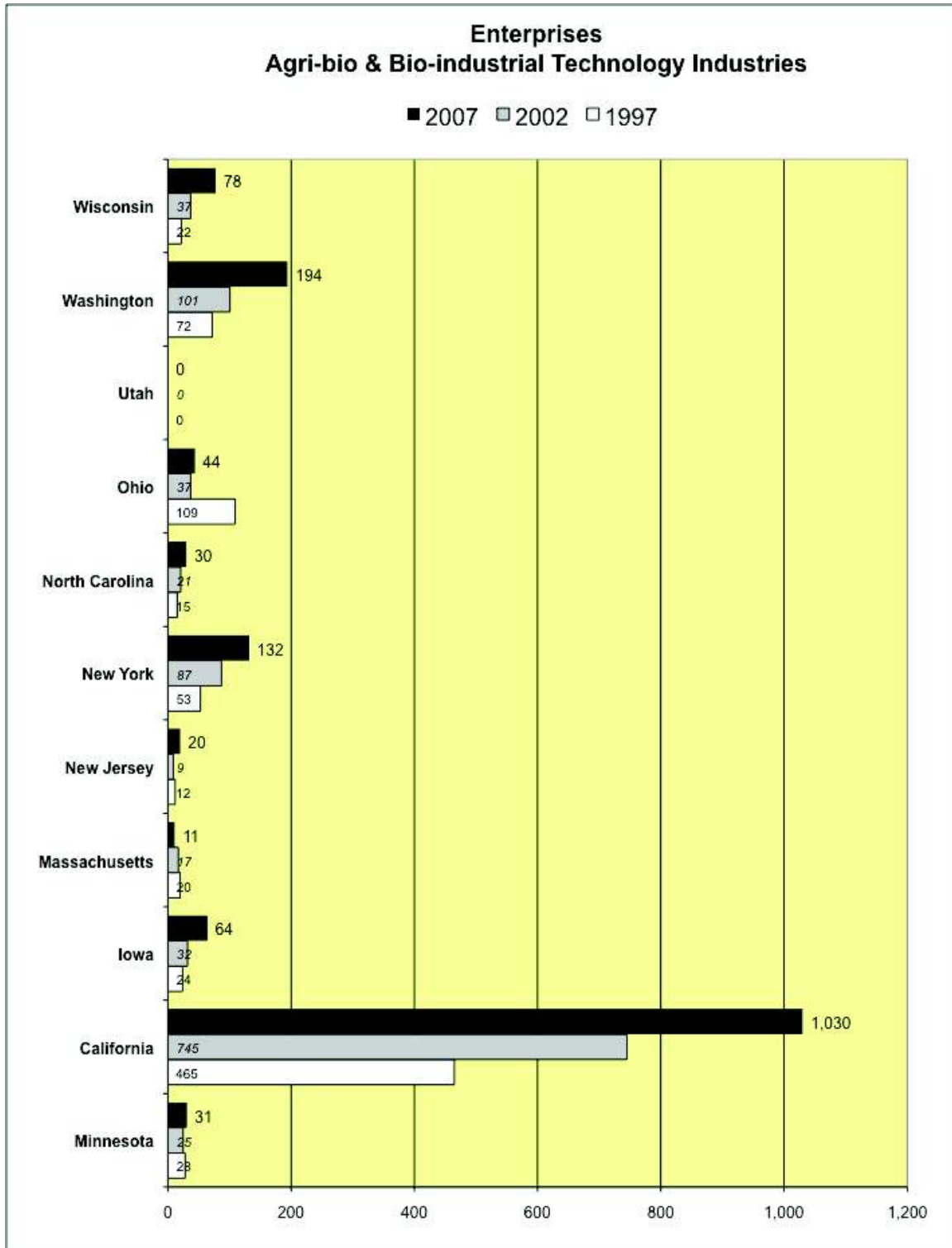
to substantial numbers of agri-bio and bio-industrial technology firms. The data may therefore still be used as a rough guide as to differences between strong, medium and weak states—the main problem being that a “zero” score for a couple of states should be interpreted to mean “very small” rather than “non-existent.” There appears to be only two states for which a serious problem of this kind is encountered: Utah (for 1997, 2002 and 2007; for employment and enterprises) and Massachusetts (for employment only for 2007). Once again, for these reasons, the results must be treated with caution. Notwithstanding these caveats, the data appear to be sufficiently robust to warrant proceeding with the calculations to paint a rough picture of the agri-bio and bio-industrial technology sector for our eleven comparison states.

Figures 23 and 24 show that, as with other fields of biobusiness technology, California enterprises are also the dominant employers in the agri-bio and bio-industrial technology industries. Additionally, the role of California as the dominant player in agri-bio and bio-industrial technology employment is increasing significantly over time, despite competition from other states. These observations hold true for both absolute employment numbers and for nationwide percentages. California's share of national employment in the agri-bio and bio-industrial technology industries increased from 24% to 37% over the decade covered by the graphs. Interpretations of California's dominant position need to be tempered by recognizing that 87% of its agri-bio and bio-industrial technology employment is accounted for by wineries and 94% of its enterprises in the sector are wineries. At the same time we need to recognize that the “imbalance” of California towards wine making does not mean for a moment that it is not an important player in the other industries within the sector. At the end of the decade California was home to over 3,600 jobs in the other fields of agri-bio and bio-industrial technology, surpassed only by Iowa in this respect; while the number of enterprises in California in the “non-winery” industries of the sector was roughly double that of Minnesota and almost as large as that of Iowa. A conclusion we may draw from this is that a state being heavily biased towards one particular sub-domain of the agri-bio and bio-industrial technology industries does not preclude it from also being successful and prominent in other sub-domains agri-bio and bio-industrial technology industries.

Figure 23 contains good news for Minnesota. During the second half of the decade total employment in the state in the agri-bio and bio-industrial technology industries increased by over 44% to over eleven hundred people, returning close to its level at the beginning of the decade; and, as Figure 24 shows, the state's share of total national employment in the sector also rose. Like California, Minnesota's employment in the agri-bio and bio-industrial technology industries is somewhat “imbalanced,” with more than half accounted for ethanol producing enterprises (which, themselves account for more than half of the state's enterprises in the sector); and presumably also like California, that bias can be leveraged to the advantage of other sub-domains in the sector or, at a very minimum, does not need to be seen as a disadvantage.

Figure 25 profiles the distribution of agri-bio and bio-industrial technology enterprises (i.e., reflecting the number of production facilities rather than people) across the eleven competitor states reviewed here. As was the case with employment, California dominates the field as a location for agri-bio and bio-industrial technology enterprises and that state's lead appears to be increasing rapidly. For example, during the five years

Figure 25: Enterprises, Agri-bio & Bio-industrial Industries—1997, 2002 & 2007





following 2002 California added almost three times as many agri-bio and bio-industrial technology enterprises to its economy than the total number of agri-bio and bio-industrial technology enterprises located in the next most prominent state, Washington, at the beginning of that period. Minnesota increased its number of agri-bio and bio-industrial technology enterprises during the period—by almost 25%—but remained a modest player on a national scale.

Given the unusually prominent role played by ethanol production in Minnesota's agri-bio and bio-industrial technology industries it may be worth taking a closer look at the development of that industry over the decade in question. The salient numbers, which are all taken from the Economic Censuses conducted by the U.S. Bureau of the Census (from 1997, 2002 and 2007), are indicated in the table below:

#### **Ethyl Alcohol Manufacturing, Minnesota, 1997 to 2007**

Year	Number of Enterprises	Number of Employees	Total Revenue
1997	7	135	\$94.3 million
2002	11	331	\$0.34 billion
2007	17	666	\$1.40 billion

Among other things, these data reveal that the pivotal role played by ethanol production within Minnesota's agri-bio and bio-industrial technology industries is not only a key characteristic of this biobusiness technology sector in the state but it has been becoming an increasingly prominent characteristic over time. At the beginning of the decade, roughly 10% of Minnesota's employment in the agri-bio and bio-industrial technology industries was accounted for by ethanol producing enterprises (which themselves accounted for about 25% of the state's enterprises in the sector). By the end of the decade, the proportion of total employment in Minnesota's agri-bio and bio-industrial technology industries accounted for by ethanol producing enterprises had risen to about 59% (and those enterprises themselves accounted for about 55% of the state's enterprises in the sector). *Ethanol appears to be the "fuel" that is powering growth in Minnesota's agri-bio and bio-industrial technology industries!*

The industry density indices for agri-bio and bio-industrial technology plotted in Figure 26 and Figure 27 reveal that California's dominant position as a location for agri-bio and bio-industrial technology enterprises and jobs stems not just from its huge economy but also from its underlying competitiveness. California scored high employment density indices and high enterprise density indices throughout the decade.

When enterprise density indices are taken in to account, Iowa, Washington and Wisconsin emerge as increasingly successful locations for entrepreneurship in agri-bio and bio-industrial technology. All three achieved progressively higher agri-bio and bio-industrial technology enterprise density indices as the decade proceeded, with Iowa, in particular, also managing to translate this in to significant employment growth.

Figure 26: Employment Density Indices, Agri-bio & Bio-industrial Industries—1997, 2002 & 2007

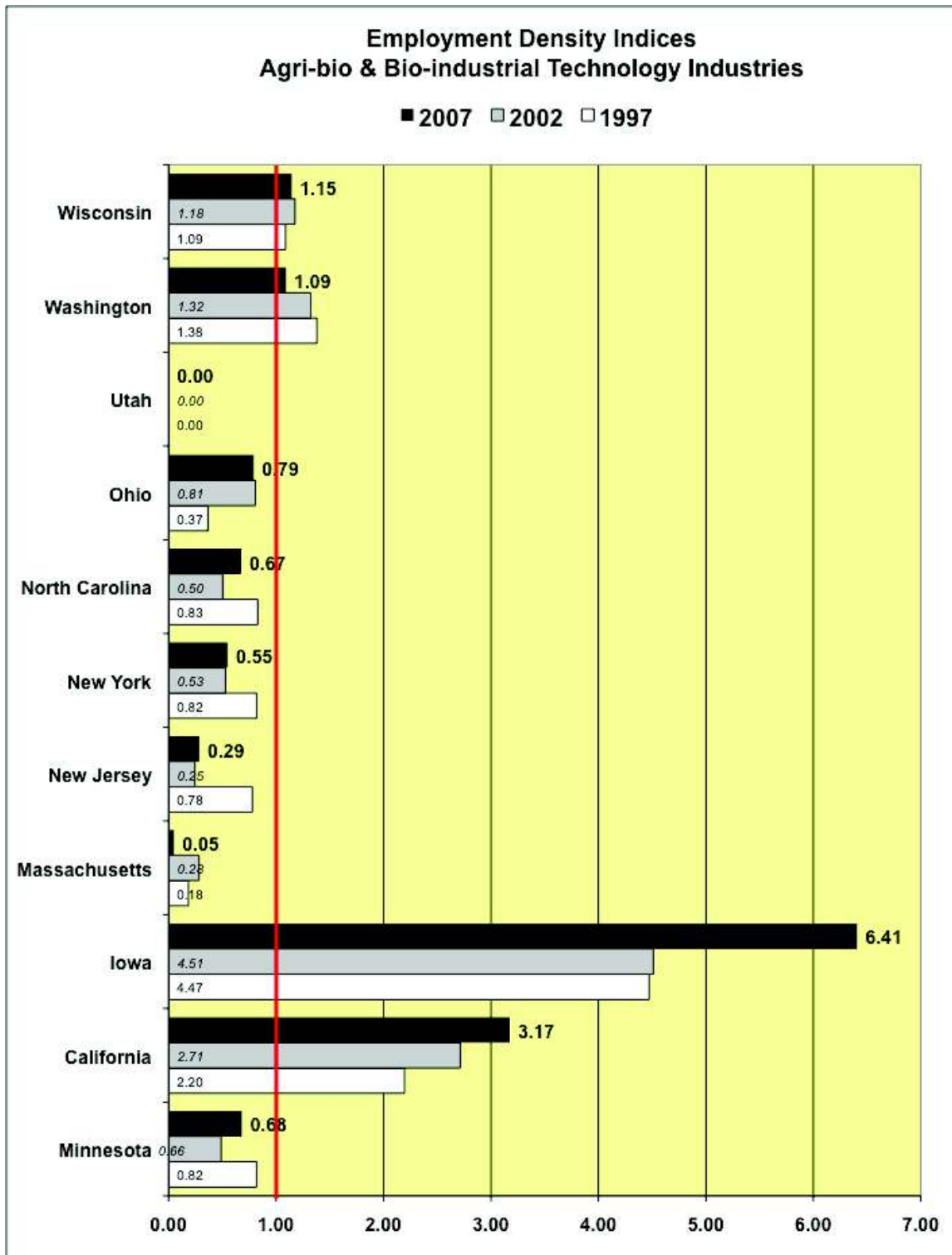
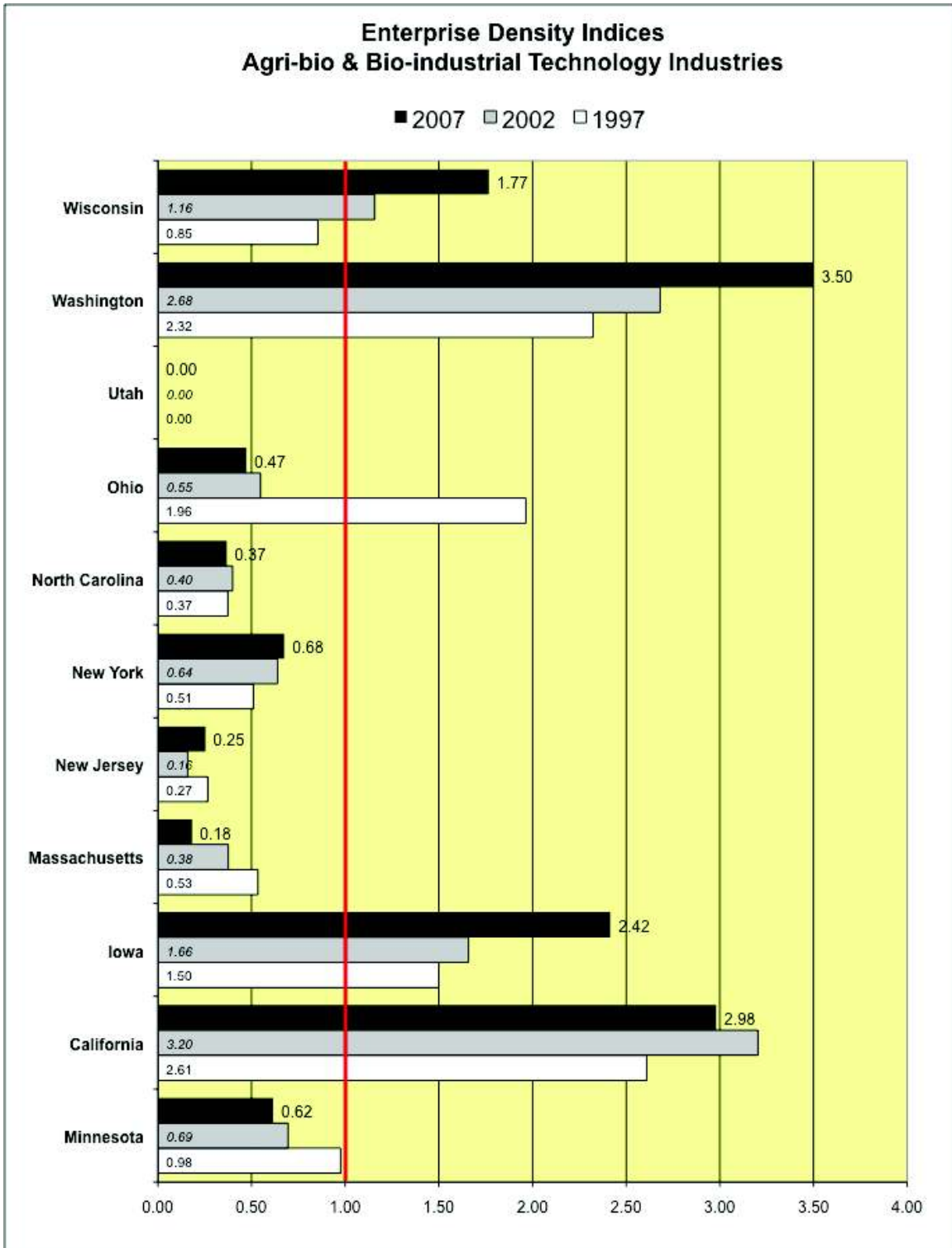


Figure 27: Enterprise Density Indices, Agri-bio & Bio-industrial Industries—1997, 2002 & 2007



The density indices reveal that Minnesota managed to perform better during the second half of the decade as a location for employment growth than it did as a location for entrepreneurship in agri-bio and bio-industrial technology, suggesting that the state has been focusing primarily on sustained investment for local business growth (predominantly, as we can see from the number in the foregoing table, in the area of ethanol production) rather than on experimentation with new business in this field. Nevertheless, as Figure 25 confirms, Minnesota did enjoy net growth in the number of agri-bio and bio-industrial technology enterprises domiciled locally from 2002 to 2007.

Minnesota's industry density indices—which sit below what one would expect, taking in to account the size of Minnesota's population and economy—suggest that, despite the encouraging growth in employment enjoyed by the state, Minnesota has not yet built the underlying foundation for sustained local employment development in the agri-bio and bio-industrial technology industries overall. The agri-bio and bio-industrial technology industries represent an area where Minnesota needs to engage in some serious strategic analysis. While the recent performance of the state in this area is positive, not negative, the modest absolute scale of the growth compared with the growth that was enjoyed by some of the other states suggests that Minnesota may need to redouble its efforts. This may, for example, include identifying a niche (such as emerging technologies in ethanol production) where the state may have a chance to set the agenda in the nation.

It is not immediately obvious what the causes might be for the state's comfortable yet less-than-stellar competitive position in agri-bio and bio-industrial technology employment, *vis-à-vis* other states. However, a plausible explanation—besides just lackluster performance—may lie with the business structure and strategy of some Minnesota firms who may spread their activities across the boundaries of multiple states. It is possible that some enterprises located in Minnesota have chosen to invest heavily in production facilities located in other states where the local conditions may be more suitable for the particular industries in question. There is some anecdotal evidence for this interpretation in the fact that the revenue-density-index for agri-bio and bio-industrial technology industries in Minnesota for 2007 was 2.13, whereas the employment-density-index was only 0.68. In other words, by the end of 2007 Minnesota enterprises were earning significantly more than double the revenue that one would expect, but employing only two-thirds the number of people that one would expect—associated with agri-bio and bio-industrial enterprises—given the size of the Minnesota economy compared with the national economy, and given the size of the agri-bio and bio-industrial industries nationwide.

If this explanation is correct then the situation may be better for Minnesota than it first appears: it looks as if a higher-than-expected income from agri-bio and bio-industrial technology investments outside the state may be getting repatriated to the benefit of Minnesotans in the form of corporate income, rather than in the form of local salaries or jobs.

## 8. Pharmaceuticals

Figure 28 plots employment levels in the pharmaceuticals industry across the same eleven states and the same three points in time that have been the focus for all sectors of the biobusiness technology industries that have been reviewed as part of this study. Figure 29 takes the same data that were used to construct Figure 28 but expresses them as percentages of the national total (i.e., the total for the United States as a whole, not just the total for the eleven comparison states), rather than as absolute employment numbers.

“Pharmaceuticals” in this context refers to the business of enterprises engaged in manufacturing pharmaceuticals, not just research and development. The formal NAICS definition for this industry category is: “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.” Firms devoted to pharmaceuticals research, in contrast, have been included within this Report within the “R&D in the life sciences” category.

Figures 28 and 29 reveal that the top pharmaceuticals employers, in descending order (ranked by either raw employment numbers or by percentages), are California, New Jersey, New York and North Carolina. California's lead over other states, as we have also found to be the case in all other sectors of the biomedical technology industry, is substantial. The Figures also reveal that the significance of Massachusetts as a player in the pharmaceuticals industry is growing. Presumably, the underlying competitiveness (see Figures 20 and 21) and rising prominence (see Figures 17, 18 & 19) of Massachusetts in research and development in the life sciences has played a role in that state's rising fortunes in pharmaceuticals manufacturing.

Figure 28 shows that, while Minnesota is a relatively minor player in the U.S. pharmaceuticals industry, the scale of the industry in Minnesota is growing. During the second half of the decade covered by the data, total pharmaceuticals employment in Minnesota grew by 76 percent (see Figure 28) and the state's share of national pharmaceuticals employment increased from 0.8% to 1.4% (see Figure 29). Minnesota's percentage growth in pharmaceuticals employment was in fact the highest of the eleven states, although it was trailed closely by Washington (at 74%) and by Ohio (at 67%). The growth in pharmaceuticals employment for the nation as a whole during that period was less than one percent, and some states—e.g., New Jersey, New York, Utah and Iowa—actually lost jobs. Minnesota's employment growth in this sector—modest though it is in terms of absolute numbers—should therefore be treated with some respect.

Figure 30 reveals that the majority of the eleven states (the exception being Washington) underwent a reduction in the number of locally domiciled pharmaceuticals enterprises between 2002 and 2007. This was in line with the national trend. The United States as a whole experienced a contraction of about 30% in its population of pharmaceuticals companies during that time period. While (unlike Washington) Minnesota was not immune to the national trend, the scale of the reduction, at about 24%, was lower than the national norm.

Figure 28: Employment, Pharmaceuticals Industry—1997, 2002 & 2007

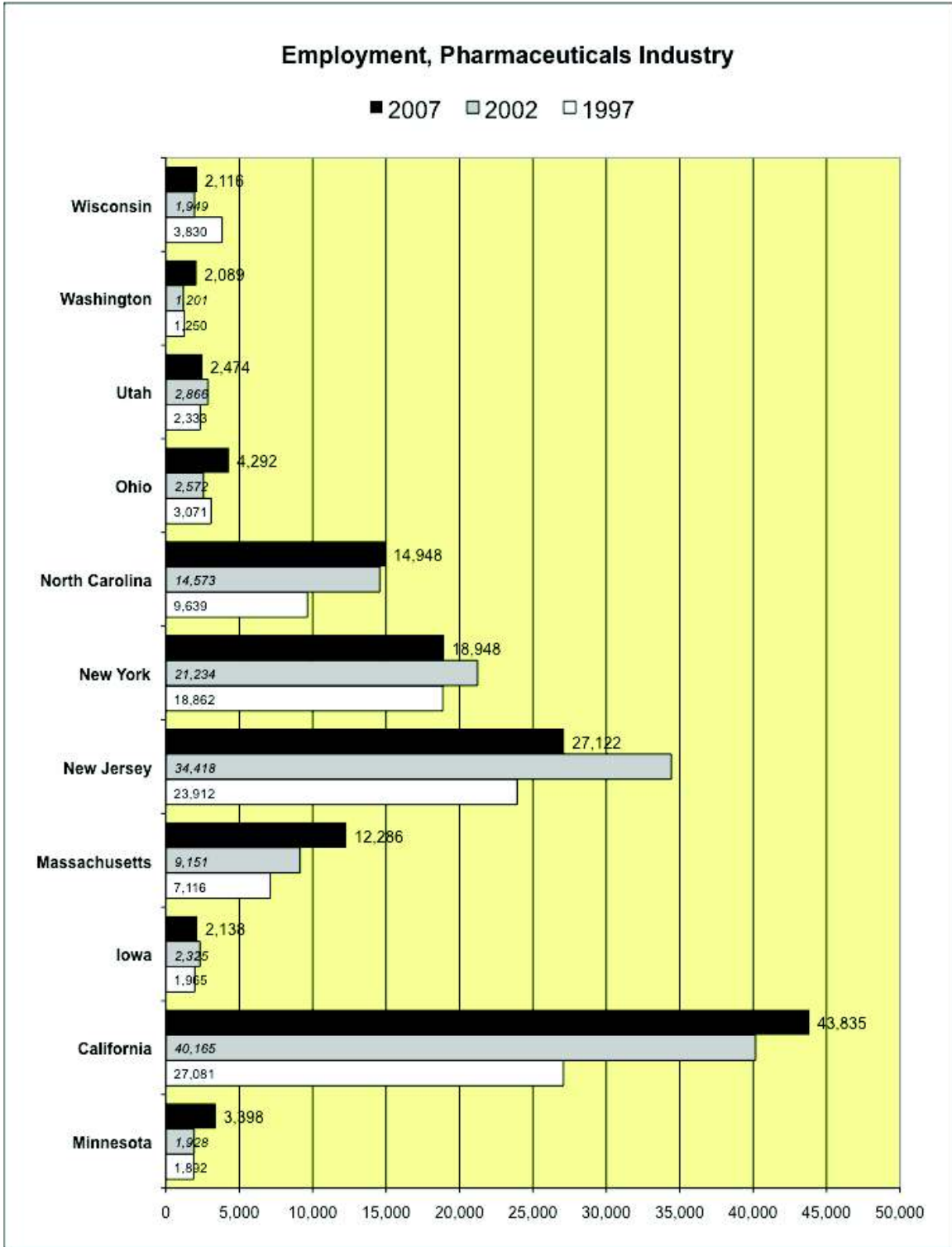




Figure 29: Percentage of Total National Employment in the Pharmaceuticals Industry—1997, 2002 & 2007

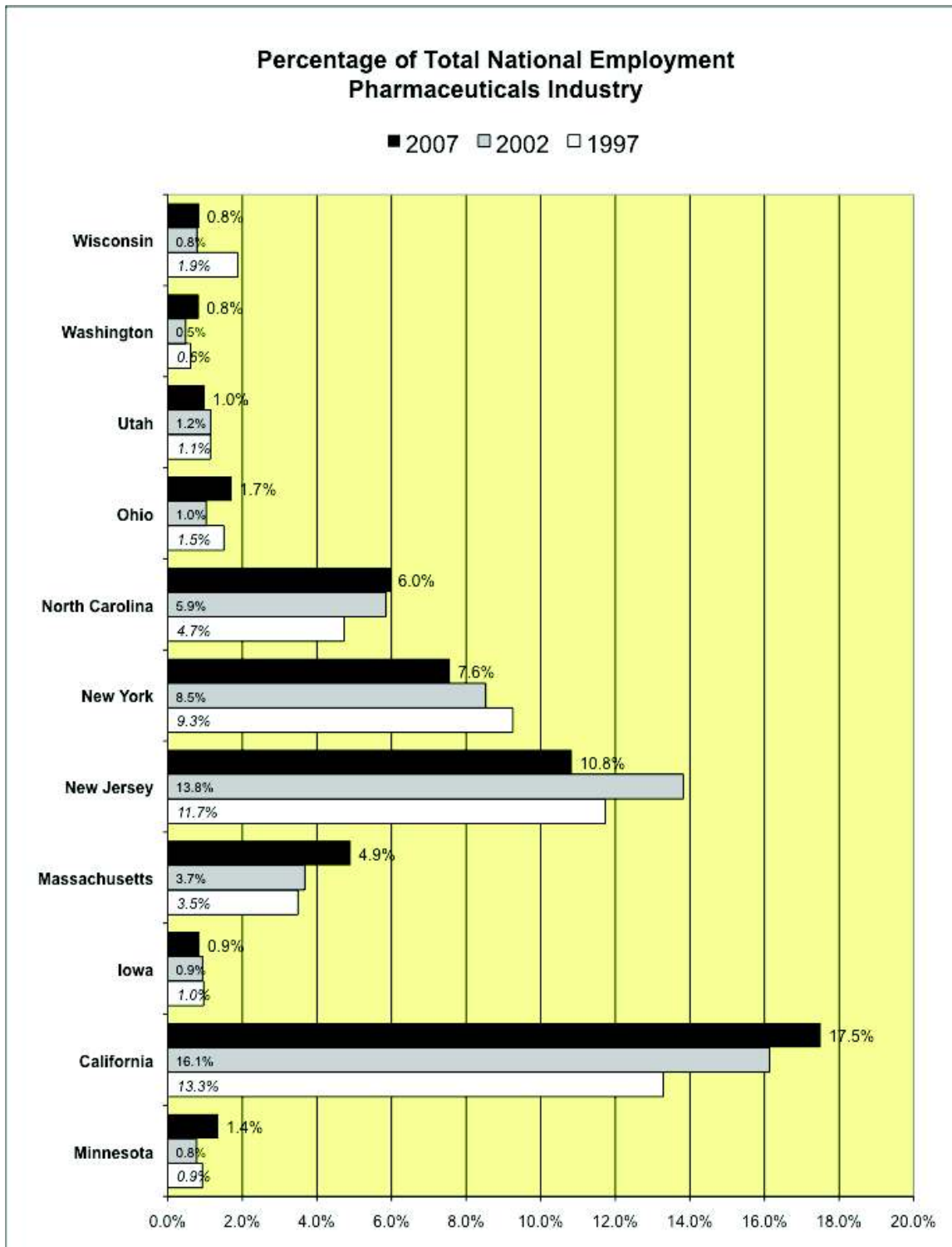
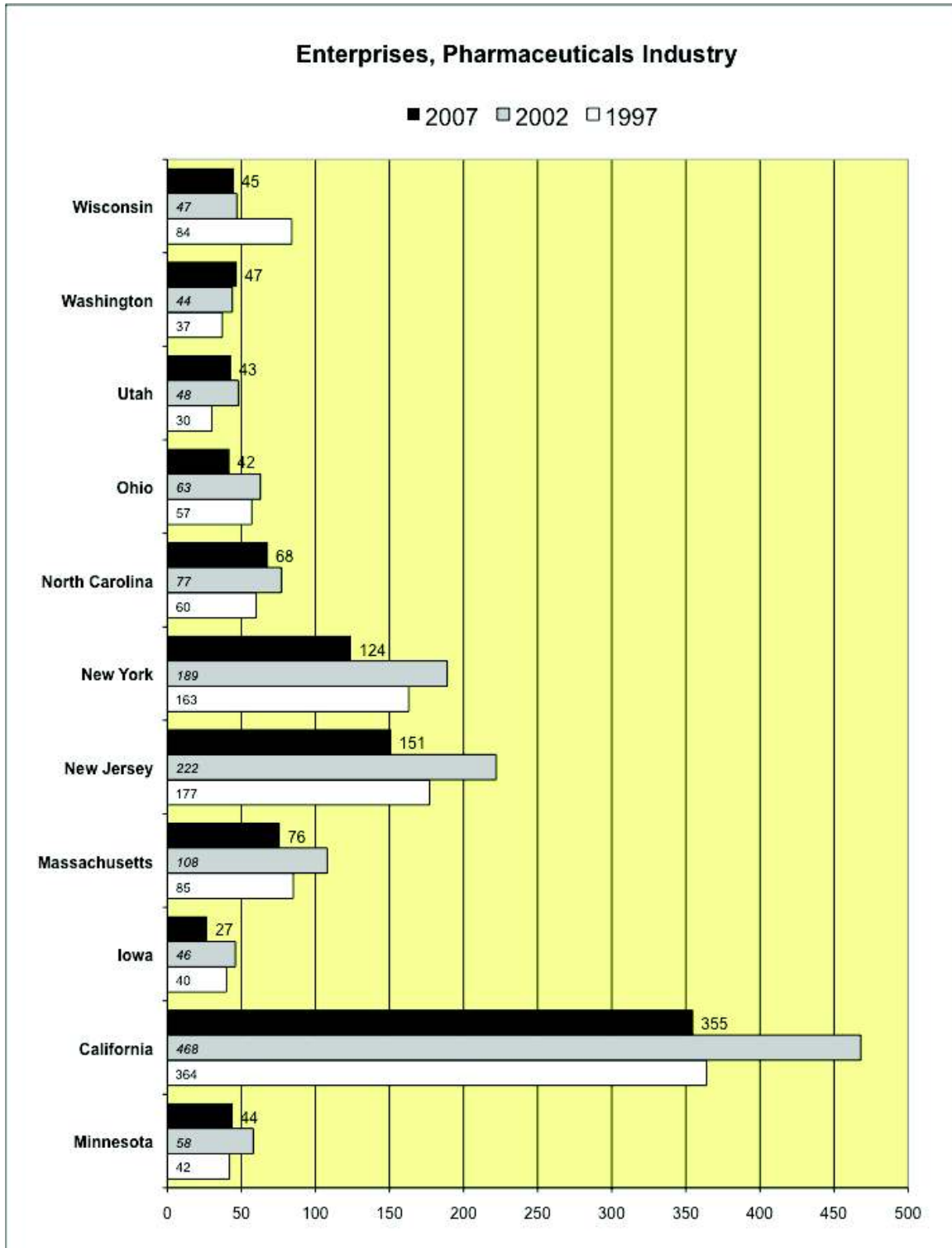


Figure 30: Enterprises, Pharmaceuticals Industry—1997, 2002 & 2007



Given that Minnesota actually increased its pharmaceuticals employment during the period in question, the contraction in the number of enterprises in the state should be interpreted as a form of industry consolidation and maturation leading to overall economic growth rather than economic loss. Earlier in this report we saw that a similar phenomenon emerged during the same period for the state's medical devices industry.

Between 2002 and 2007 the average size of pharmaceuticals enterprises in Minnesota increased from 33 people per firm to 77 people per firm, representing an upward shift of 132 percent. The average increase in pharmaceuticals firm size throughout the United States during the same period was 44 percent. Thus, Minnesota's pattern of development for its pharmaceuticals industry during the second half of the decade—emphasizing internal employment growth through existing firms—was more pronounced than elsewhere in the country.

Figures 31 and 32 plot the pharmaceuticals industry density indices for Minnesota and the ten other competitor states. The first observation that arises from these two Figures is that New Jersey stands out as an extraordinarily competitive state in the generation of employment in pharmaceuticals, taking in to account the size of the New Jersey economy *vis-à-vis* the national economy and the size of the pharmaceuticals industry nationwide. The enterprise density indices also reveal that New Jersey has achieved its relatively strong position as a pharmaceuticals employer not simply as a result of that state being the home to a number of well-established multi-national pharmaceutical corporations but also due to its high level of entrepreneurship in pharmaceuticals. New Jersey's enterprise density index for pharmaceuticals (at 2.7) is the highest among the eleven competitor states and has increased incrementally throughout the decade since 2002. It is worth noting that the productivity of Massachusetts in generating both jobs and enterprises in pharmaceuticals has also been increasing rather impressively during the decade.

During the second half of the decade Minnesota increased its productivity in generating both employment and enterprises in the pharmaceuticals industry; and, with an enterprise density index of 1.23 at the end of the decade, Minnesota's performance in pharmaceutical entrepreneurship was greater than what one would expect, all other things being equal.

Overall, Minnesota performs relatively more strongly in pharmaceuticals entrepreneurship than it does in generating growth in pharmaceuticals employment. Nevertheless, having said that, the state's performance in the generation of new jobs in pharmaceuticals in recent years is very encouraging. As illustrated by the results in Figures 33A and 33B, Minnesota managed to achieve a dramatic turnaround from declining employment density indices during the first half of the decade to attaining the strongest positive increase of all eleven competitor states in employment density during the second half of the decade. In other words, Minnesota performed above the expected level in generating pharmaceuticals employment to a greater degree than any of the other competitor states (although, both Ohio and Washington followed close behind)—that is, it was the “best improved.” In summary, while Minnesota is far from being a dominant player in the U.S. pharmaceuticals industry and while other states such as Massachusetts and North Carolina appear to be maintaining significant leads over Minnesota, Minnesota's pharmaceuticals industry is playing a significant, and apparently increasingly important, role in the state's biobusiness technology sector.

Figure 31: Employment Density Indices, Pharmaceuticals Industry—1997, 2002 & 2007

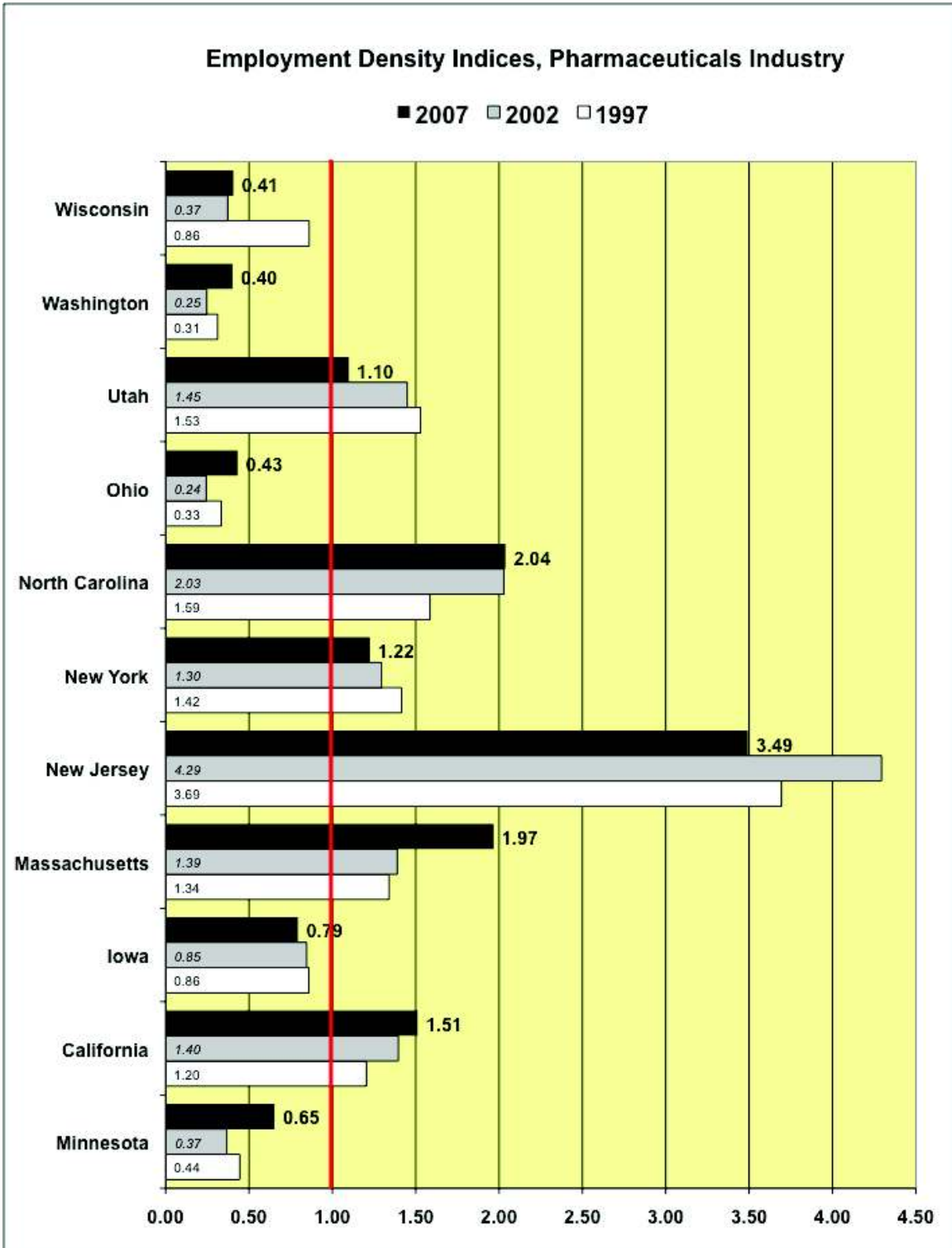


Figure 32: Enterprise Density Indices, Pharmaceuticals Industry—1997, 2002 & 2007

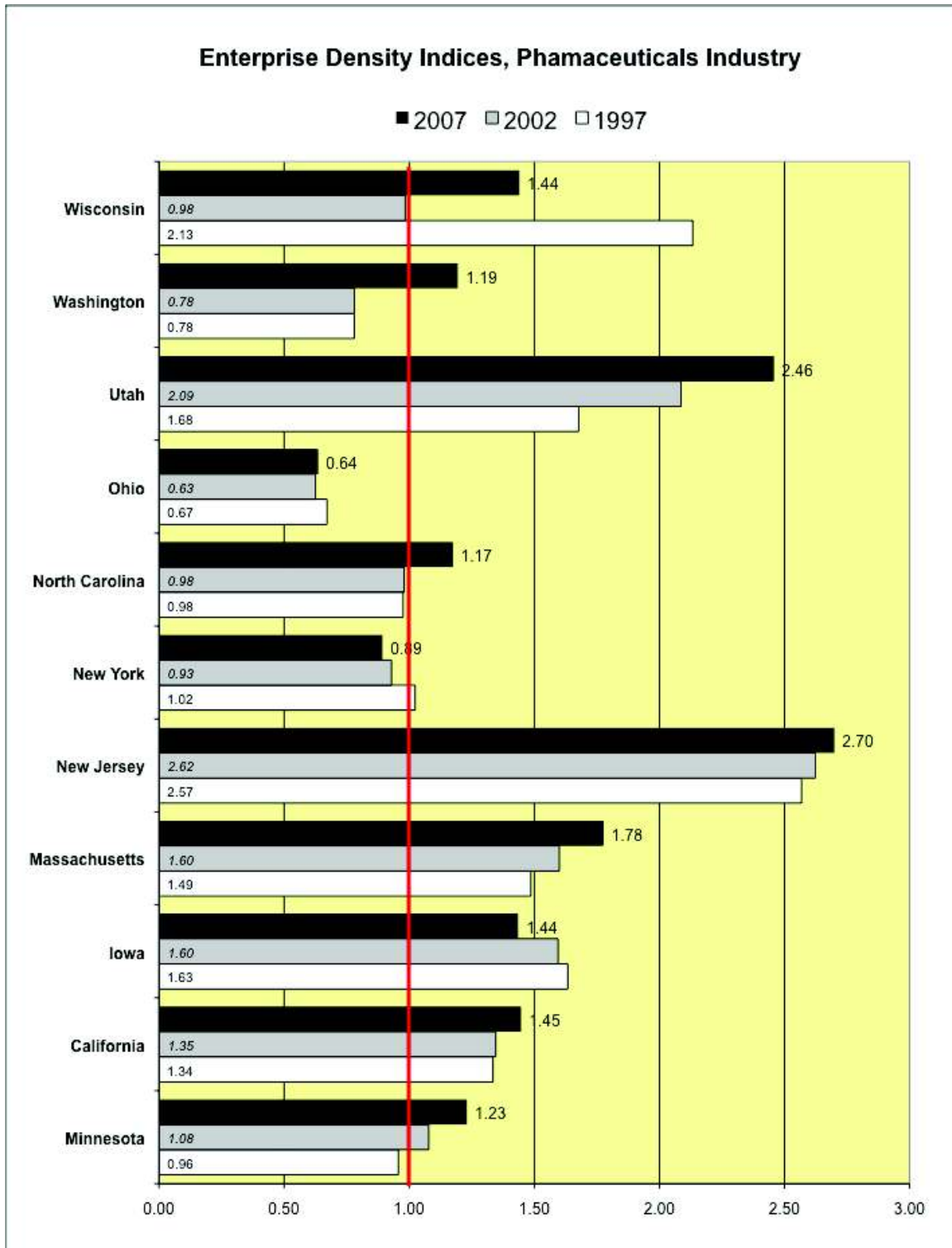


Figure 33A: Percentage Change in Employment Density Indices, 1997-2002, Pharmaceuticals Industry

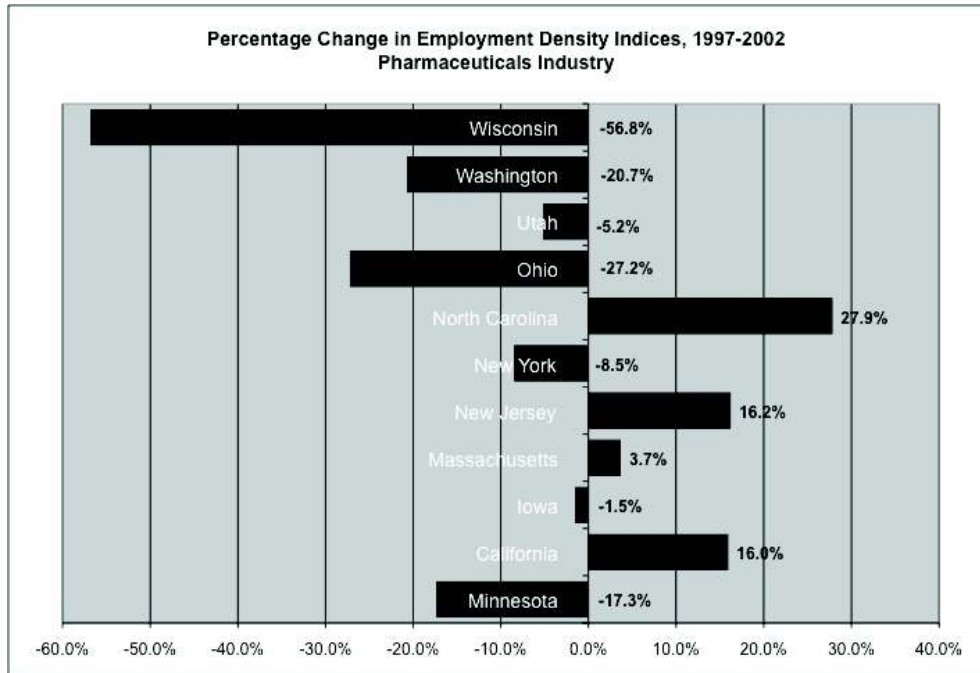
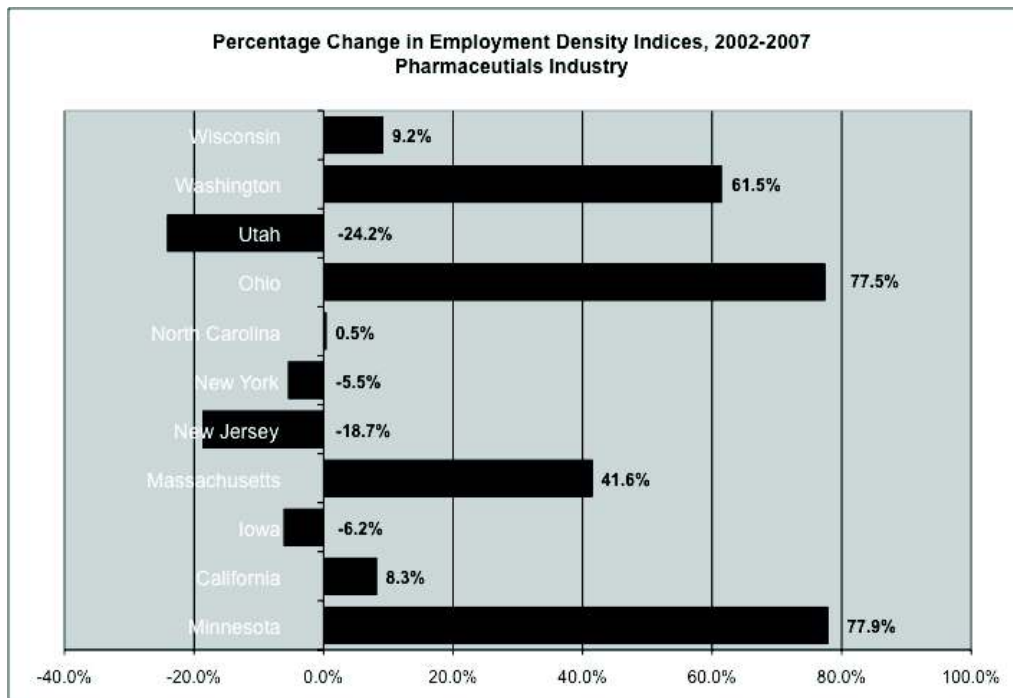


Figure 33B: Percentage Change in Employment Density Indices, 2002-2007, Pharmaceuticals Industry





The convergence between the various fields of biobusiness technology that was recognized during the first statewide biobusiness assessment may partly explain why Minnesota has raised its game in the pharmaceuticals sector, despite strong competition from other states; and it may also provide a persuasive justification for Minnesota continuing to invest in this area, despite the non-dominant position it occupies nationwide.

## 9. Summary and Conclusions

The results of the most recent U.S. Economic Census that were released during 2010 contain good news for Minnesota. **During the half-decade following 2002 the biobusiness technology economy of Minnesota, overall, grew significantly and improved its competitive position in most respects.** In short, the state of Minnesota managed to achieve a substantial turnaround in the status and competitiveness of its biobusiness technology economy. That this turnaround was accomplished is especially encouraging in view of the fact that during the preceding half-decade the biobusiness technology industries in Minnesota had in many respects actually lost ground.

The first statewide assessment report of the BioBusiness Alliance of Minnesota ended with the following conclusion, regarding the biobusiness technology industries of Minnesota: “... *the biobusiness “train” has not yet left the station. However, we have discovered through our investigations that—metaphorically speaking—other states and other communities are busy investing in their own biobusiness “railway” systems, complete with tracks, stations, rights of way, new types of locomotives and new rail support services. Minnesota needs to plan and implement its next-generation “biobusiness rail system” with renewed vigor and urgency ... and in a manner that truly reflects the distinctive technological capabilities of the state. The dynamism, uniqueness and recently renewed growth of the employment and business activity in our state’s biobusiness sector provides solid grounds for hope that the necessary steps can be taken to sustain Minnesota as a first-tier global player in the biobusiness fields where it can truly be among the best of the best.*”<sup>20</sup> This report of the second statewide assessment has shown that both the caution (about mounting competition from other states, amidst some faltering steps within the state) and optimism (about Minnesota’s underlying capability to respond to the challenge) expressed in that first report were justified. Some of Minnesota’s competitor states have continued to enhance their position in biobusiness technology since 2002 thereby, to some degree, threatening the comfort of Minnesota’s incumbent biobusiness technology enterprises; but in the mean time Minnesota has also apparently managed to make real progress in planning and implementing its “next generation biobusiness rail system” (to continue with the metaphor employed in the previous report). The upward swing in Minnesota’s biobusiness technology fortunes since 2002 may provide inspiration and grounds for hope to the state’s current biobusiness leaders.

---

<sup>20</sup> *BioBusiness* (2006), page 62.

A summary of the trends in Minnesota's biobusiness technology industries during the half-decade following the previous U.S. Economic Census, together with highlights of trends from the previous half-decade prior, is provided in Figure 34. The most salient result of this study, reflected in Figure 34, is that employment in Minnesota's biobusiness technology enterprises grew significantly (by about 23%) from 2002 to 2007, more than making up for the ground that was lost during the previous half-decade. As was mentioned earlier in the report, this news is especially significant since Minnesota was the only state out of eleven that actually appeared to lose biobusiness technology industry employment overall during the five years from 1997 to 2002.

Not only did Minnesota increase its number of biobusiness technology jobs during the second half of the decade, the state also increased its *productivity in generating biobusiness technology jobs relative to other states*. Minnesota managed to maintain its above-average level of competitiveness (*vis-à-vis* employment density) continuously throughout the decade following 1997; and between 2002 and 2007 the state managed to significantly improve its relative position. Minnesota's biobusiness technology employment density index increased from 1.14 in 2002 to 1.43 in 2007. In short, Minnesota managed to turn around its previous downward trend in biobusiness technology competitiveness into an impressive upward swing. The scale of the upwards shift in Minnesota's competitiveness, as indicated by its dynamic propensity for generating employment through biobusiness technology, was the greatest of any of the eleven states reviewed during the assessment project.

The vast majority of the biobusiness technology industry density indices for Minnesota—both the indices for the aggregate industry and the indices for each of the constituent industry segments within the aggregate biobusiness technology industry—improved from 2002 to 2007. In fact, all of the employment density indices and all of the enterprises density indices for Minnesota—with the one exception of the enterprise density index for agri-bio & bio-industrial technology—increased during that time period. Thus, Minnesota became more competitive within the United States during the most recent half-decade for which U.S. Economic Census data are available.

The story becomes a little more complex when comparisons are made with the dynamic positions of individual competitor states. The situation varies from case to case (i.e., from industry segment to industry segment). For example, in the medical devices industry—which is arguably the most important segment for Minnesota—Minnesota is clearly number one (i.e., it has the highest employment density index of all eleven states). For the enterprise density index (for medical devices) Minnesota improved its score in comparison with the other states, but maintained its rank as third on the list. So, for medical devices, Minnesota rose in the ranks for its employment density index in comparison with other states, to regain the top position, but maintained its previous position on the list for its enterprise density index in comparison with other states. Nevertheless, as explained earlier in the report, even though two other states (Utah and Washington) scored higher enterprise density indices during the period in question than Minnesota, Minnesota managed to increase its share of nationwide medical devices industry employment compared with those two states. The business of Minnesota's medical devices enterprises grew during the decade thereby reinforcing the state's competitive advantages in the field and adding to the net stock of medical devices jobs in the state.

**Figure 34: Overall Economic Trends, Biobusiness Technology Industries (and the Macro-economy) 2002- 2007**

Economic Variable	Medical Devices	R&D in the Life Sciences (excluding the academic sector)	Agri-bio and Bio-industrial Technology	Pharmaceuticals	Total Biobusiness Technology Industries	All Industries (in the macro-economy)
Number of employed people (in Minnesota)	Up	Down slightly	Up	Up	<b>Up</b>	Up slightly
Percentage of U.S. workforce	Up	Up slightly	Up	Up	<b>Up</b>	Down slightly
Number of Enterprises (in Minnesota)	Down	Up	Up	Down	<b>Down</b>	Up
Percentage of U.S. Enterprises	Up	Up	Down	Down slightly	<b>Up</b>	Down
Relative productivity in generating employment* 2002-2007	Up	Up	Up	Up	<b>Up</b>	Down slightly
Overall Competitiveness 2002-2007	Up	Up	Up slightly	Up slightly	<b>Up</b>	Stable
<i>Relative productivity in generating employment* 1997-2002</i>	<i>Down</i>	<i>Down</i>	<i>Down</i>	<i>Down</i>	<i>Down</i>	<i>Up slightly</i>
<i>Overall Competitiveness 1997-2002</i>	<i>Down</i>	<i>Down</i>	<i>Down</i>	<i>Stable</i>	<i>Down</i>	<i>Stable / Up slightly</i>

- As indicated by changes in the pertinent *Employment Density Index* over time.

During the second half of the decade to 2007 employment in Minnesota in the agri-bio and bio-industrial technology industries increased by over 44% and the state's share of total national employment in the sector also rose. Ethanol production is the dominant sub-domain of Minnesota's agri-bio and bio-industrial technology industries and over time has become increasingly so.

While the recent performance of the state in this area is positive, not negative, the modest absolute scale of the growth compared with the growth that was enjoyed by some of the other states suggests that Minnesota may need to redouble its efforts. This may, for example, include identifying a niche (such as emerging technologies in ethanol production) where the state may have a chance to set the agenda in the nation. Nevertheless, notwithstanding the fact that a number of other states seem to have moved more aggressively than Minnesota in to the agri-bio and bio-industrial technology industry space during the last decade, it appears that Minnesota remains active in the area, leveraging some of its emerging capabilities in commercial life sciences R&D to develop new business models in agri-bio and bio-industrial technology. Some other U.S. states may be benefitting, in terms of employment generation, from Minnesota's efforts in this domain; but Minnesota's agri-bio and bio-industrial technology companies seem for now to be generating increased revenue for the state from their geographically dispersed activities.

As was the case at the time of the previous statewide assessment project, Minnesota's economy is more dependent upon the biobusiness technology industries than is the norm for the United States. During the five years leading up to the most recent Economic Census, the relative emphasis in Minnesota upon the biobusiness technology economy increased. At the end of 2002 the proportion of Minnesota's economy (measured as employment) based on the biobusiness technology industries was 113% of the equivalent proportion for the United States as a whole. Five years later this had risen to 143% of the equivalent proportion for the nation. Hence, how the state manages its biobusiness technology industries matters for the overall health of the state's economy much more in Minnesota than it typically does elsewhere in the country.

As was also the case at the time of the previous statewide assessment project, Minnesota's biobusiness sector is distinctive. Most importantly, the medical devices industry plays an extraordinary role in the mix of biobusiness technology industries in the state. The percentage of biobusiness employment accounted for by the medical devices segment is more than twice as large in Minnesota than it is in the nation as a whole; and the ratio of Minnesota to the nation (in the respective percentage of biobusiness employment accounted for by the medical devices segment) increased from 202% to 231% during the decade leading to the most recent Economic Census. Thus, the dominant role of medical devices in Minnesota's biobusiness technology industry is growing over time, not diminishing.

The salience for Minnesota, compared with other states (especially in areas of technological convergence) between the devices segment and other segments, was recognized in the previous statewide assessment report. As we enter the second decade of the Twenty First Century it appears to be imperative for Minnesota to enhance its capacity to leverage the strength of the medical devices segment of the biobusiness economy for the other segments. Accordingly, there may be value for enterprises in the other segments in the overall biobusiness technology industry to consciously seek further

opportunities for leveraging the strength and momentum of the medical devices segment to their own advantage. Conversely, medical devices firms might find opportunities to further enhance their business by seeking ways to leverage innovations emanating from the other segments.

The leaders of Minnesota's impressive recent biobusiness technology resurgence might be able to energize their efforts to convert this resurgence in to a sustainable competitive advantage for the state through facilitating the enhancement of linkages between the medical devices segment and other segments of the biobusiness economy in Minnesota.

## Appendix 1

### Definitions of Basic Biobusiness Concepts

#### **Biobusiness**

*Biobusiness is economic activity devoted to the development or commercialization of bioscience or bioscience-related technologies, products or services.*

In other words, biobusiness is technology-based economic activity centered on biology. Biobusiness deals with the spectrum of enterprises from start-ups to established firms, together with associated infrastructure and support services. In this project, however, we have left analysis of the associated infrastructure and support services to another occasion. We have instead focused our analysis on a narrower set of enterprises: those whose primary business is the development or commercialization of biological technology. We call these organizations “biobusiness technology enterprises” (to be defined and explained below).

#### **Bioscience**

*Bioscience is knowledge based on the life sciences, especially emerging molecular and cellular biology, and also science applied to human health, agriculture, and bio-related industry.*

Bioscience is a key source of what may be called "biobusiness technology" or "biological technology."

#### **Life Sciences**

*The life sciences are the collection of sciences concerned with the study of living organisms, including biology, botany, zoology and the medical sciences, but also including other biology-related fields such as biochemistry or ecology that deal with the functions of organisms, and the relationships between organisms and between organisms and their environments.*

Sometimes, the terms “life sciences” and “biosciences” are used interchangeably.

#### **Biobusiness Technology**

*Biobusiness technology is technology devoted to the biological domain, as either a system of tools or as a field of application.*

Put simply, biobusiness technology is technology focused on biology. It is the technological foundation of biobusiness. Biobusiness technology could, in principle, also be called "biological technology."

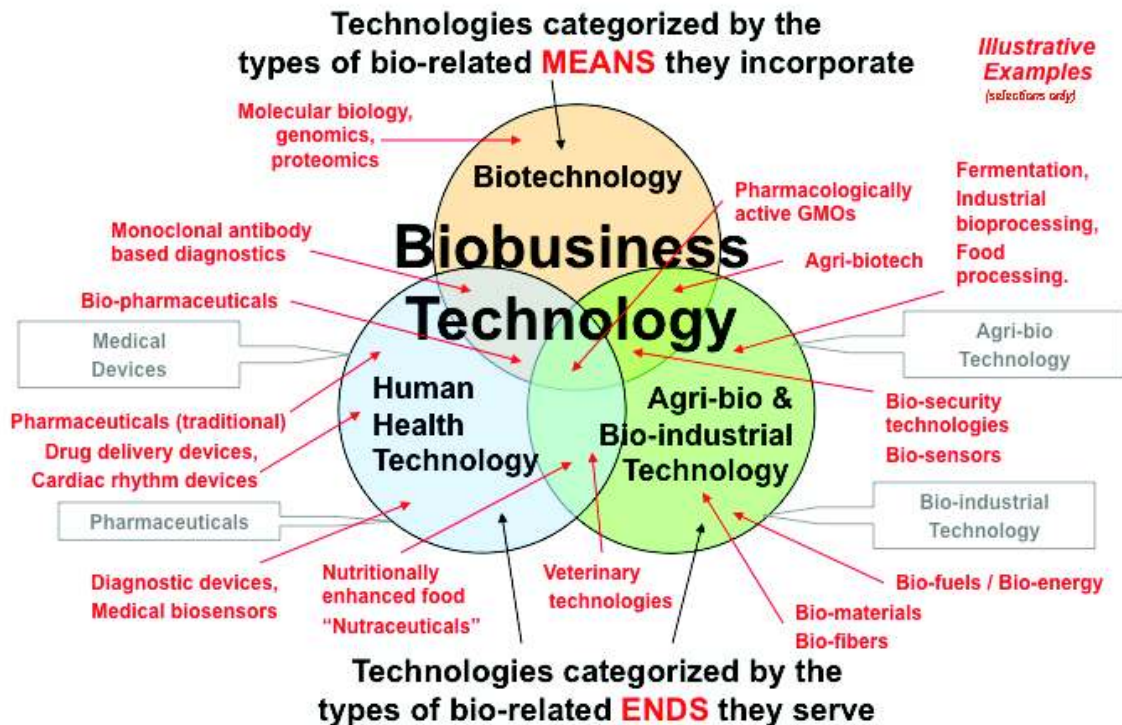
Strictly speaking, the term “biotechnology” could be used as a label for this domain of technology. However, during the last two decades that term has been taken to describe a narrower set of biological technologies, centered on the application of certain contemporary fields of science including molecular biology, cell biology, microbiology, genomics and proteomics. We have therefore been forced to coin some other terms to



embrace the broad scope of technological activity focused on the biological world. We have chosen not to follow the fashion of using "bioscience" for that purpose, because we believe that science—specifically, bioscience—is just one element (albeit a critically important element) of that domain. Hence, we use the term "biobusiness technology" to cover what we would otherwise wish to label as "biotechnology."

Figure 35

**Fields of Biobusiness: Biological Technology**



Source: Dr. Ketava W. Kolloughby, 1996, 2003.

The concept of biobusiness technology is illustrated in Figure 35. Biobusiness technology incorporates both technologies defined according to the means (tools) they employ and technologies defined according to the ends (market-applications or purposes) that they are intended to serve.

Biotechnology is a category of technologies which, properly understood, may be grouped together because of a common (or complementary) set of scientific-cum-technical means which they incorporate. In contrast, both human health technology and agri-bio / bio-industrial technology are categories of technology which, properly understood, may be grouped together because of a common (or complementary) set of ends (purposes or market-applications) which they serve.

A particular technology may be classified simultaneously according to both the ends (or markets) that it serves and the means (or tools) that it employs. For example, a diagnostic test kit based upon monoclonal antibody technology may be simultaneously classified as both a biotechnology product and a human health technology product.

Likewise, a genetically engineered micro-organism for digesting oil from an aquatic ecosystem may be simultaneously classified as both a biotechnology product and as an agri-bio / bio-industrial technology product (but not as a medical technology product.) Similarly, a specialized polymer for use in surgical implants may be classified as a medical technology product but not necessarily as a biotechnology product.

### **Biotechnology**

*Biotechnology is technology consisting of biological systems that are engineered at the micro level for practical applications.*

More formally, biotechnology may be defined as technology in which biological systems are conceived, controlled, or influenced through the application of molecular biology, cell biology, microbiology, genomics or proteomics, and which are employed as means towards the attainment of practical ends. Biotechnology may be directed towards any practical purpose, including human health or agri-bio and bio-industrial-bio applications, and also many other applications; but it may only incorporate means drawn from certain specified fields pertaining to the biosciences.

### **Human Health Technology**

*Human health technology is technology directed primarily towards medical applications.*

It includes medical devices (both diagnostic devices and therapeutic devices), pharmaceuticals, and complex medical-technology systems (combining either chemicals or other technologies). Human health technology may incorporate technical means from any field of technology, including biotechnology.

### **Agri-bio and Bio-industrial Technology**

*Agri-bio and bio-industrial technology is technology directed primarily towards applications in biosystems (outside the human body).*

It includes selected agricultural, animal husbandry, aquaculture, food-processing, food-supplement, environmental-management, or life-sciences technologies. Agri-bio and bio-industrial technology may incorporate technical means from any field of technology, including biotechnology; but it must be directed towards applications in living systems or biology-related contexts.

### **Biobusiness Technology Enterprise**

*A biobusiness technology enterprise is a technology-based business focused on biology.*

More particularly, a biobusiness technology enterprise (“BTE”) 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 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.<sup>21</sup> A biobusiness technology enterprise could also be called a “biological technology enterprise.”

It is important to recognize that a biobusiness technology enterprise may be devoted to the goal of developing or commercializing bioscience-related *services*, as well as technologies and products. Research and development activities are service activities, and commercialization of R&D is therefore an example of the commercialization of services. Only certain kinds of services—those that are specifically part of bioscience or that are closely related to bioscience (e.g., technical services employed in bioscience labs)—are eligible for inclusion as the “services” to be commercialized. In short, to be included as an essential element of what qualifies a biobusiness technology enterprise as a BTE, services must be technological services, and not just professional services or business services. An example of a service that could be commercialized might be a genetic testing technique based upon genomics research. A genetic testing technique is not a “thing,” even if it may require the use of “things”—rather, it is a service—but it is special kind of service, a technological service.

---

<sup>21</sup> While a university research laboratory might, in principle, qualify as a biobusiness technology enterprise, in this study—which is limited to enterprises classified under the NAICS categories listed in Appendix 2 (following)—university laboratories, government laboratories and other not-for-profit institutes similar to university or government laboratories, are excluded from the formal data analysis.

## Appendix 2

### Definitions of Selected NAICS Categories Employed in this Study to Characterize the Domain of the Biobusiness Technology Industries

#### **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 (*for 1997 & 2002*)**

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 541711 Research and Development in Biotechnology (*for 2007*)**

Establishments primarily engaged in conducting biotechnology research and experimental development. Biotechnology research and experimental development involves the study of the use of microorganisms and cellular and biomolecular processes to develop or alter living or non-living materials. This research and development in biotechnology may result in development of new biotechnology processes or in prototypes of new or genetically-altered products that may be reproduced, utilized, or implemented by various industries..

#### **NAICS 5417101 (part) *Selections of Research and Development in the Physical, Engineering & Life Sciences (except Biotechnology) (for 2007)***

Establishments primarily engaged in conducting research and experimental development in

---

medicine, health, biology, botany, ... agriculture, fisheries, forests, pharmacy, and other life sciences including veterinary sciences. This sub-category excludes biotechnology R&D as defined in NAICS 541711.

**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.

*Note: The above definitions were extracted from the web site of the U.S. Census Bureau. Internet address: <http://www.census.gov/> (extracted: 02/16/2006 and 21/11/2010).*

## Appendix 3

### Data Sources and Changes in the NAICS Classification System Since 2002

The primary data sources for this study were the Economic Censuses of 1997, 2002 and 2007 conducted by the U.S. Bureau of the Census together with data from the various surveys of non-employers associated with the Economic Census.

There have been some—on the whole, positive—changes in the NAICS classification system since 2002 that make the system more appropriate for biobusiness. Most importantly, “Research and development in biotechnology” has been raised from a relatively obscure 8-digit NAICS sub-category to the level of a full 6-digit standard NAICS category. Secondly, relevant portions of the old NAICS 339111 category (“Laboratory apparatus & furniture manufacturing”) have now been placed under the updated NAICS 339113 (“Surgical appliance & supplies manufacturing”) category. Thirdly, data for non-employer establishments have now been conveniently assembled by the Bureau of the Census along with data from employer establishments, thereby reducing considerably the amount of work required for an analyst to build a robust picture of all players in an industry.

These enhancements to NAICS, especially its treatment of biotechnology, have the added advantage that, from now on, there will hopefully be closer alignment between data generated by the U.S. Bureau of the Census and data generated by the U.S. Department of Labor on industries pertinent to biobusiness. Unfortunately, however, along with this positive change, the Bureau of the Census has stopped publishing data for industries with NAICS codes any finer than 6 digits. This is a problem for studies of biobusiness, since the Economic Census now lumps Life Sciences R&D (other than biotechnology) together with R&D in the Physical Sciences and Engineering, and provides no easy way for the differences to be teased out—since these differences appear at the 7-digit or 8-digit level. It is important to address this data issue because significantly more than half of the enterprises included by both the U.S. Bureau of the Census and the U.S. Department of Labor in the polyglot industry classification, “NAICS 541712 (R&D in the physical, engineering, and life sciences (except biotechnology)),” do not belong in the life sciences.

This problem has been solved in this study by selecting the appropriate portions of NAICS 541712 (“R&D in the physical, engineering, and life sciences (except biotechnology)”), representing only the life sciences sub-category of NAICS 541712, by systematic estimation and projections based on analysis of 1997 data and 2002 data in NAICS 5417101 and NAICS 5417102, articulated separately for each state and for each economic indicator.



## Appendix 4

### Explanation and Definition of Industry Density Indices

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:

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

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

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

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  $\text{industry}_x$  in  $\text{city}_n$  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  $\text{industry}_x$  accounted for by employment for  $\text{industry}_x$  in  $\text{city}_n$  tells you that the relative position of  $\text{city}_n$  in  $\text{industry}_x$  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  $\text{city}_n$  has actually improved as a place for employment in  $\text{industry}_x$  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<sub>*x*</sub> in city<sub>*n*</sub> tells you that city<sub>*n*</sub> has become stronger for employment in industry<sub>*x*</sub>—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.

## Appendix 5

### Bio Production and Processing Industries

There are many industries in Minnesota that, for the most part—according to the definitions employed in this report—are not part of the “biobusiness technology” domain, but that are nevertheless prominent in the broader set of “biobusiness” industries and play a major role of Minnesota’s total economy and society. For convenience, these sets of economic activities are labeled here as the “bio production and processing” industries. The firms active in these industries make their contribution to the economy through the production, harvesting, gathering and processing of natural biological products, including the transformation of those natural raw materials in to advanced biomaterials and other bio-based products.

These industries include, for example, agriculture, forestry, fishing, hunting, food processing (including dairy-products processing), natural beverage production (including beer making and wine making), fermented sauce and additive production, timber processing and wood-based materials production, bio-fuel production and other forms of natural bio-based materials processing and production. Some of the firms that sit under the general umbrella of the *bio production and processing industries* also belong within the more narrowly conceived group of industries labeled here as the “biobusiness technology” industries, but for the most part they do not fit there. The lion’s share of firms in the *bio production and processing industries* do not center their business on biological technology but rather make use of technologies from a variety of fields to manage the production and processing of natural (bio based) resources. Having said that, the scale and scope of these industries is such that their role and influence in the wider biobusiness economy deserves careful study. Additionally, the practical, technical, organizational and historical linkages between the biobusiness technology industries and the *bio production and processing industries* makes it prudent for us to look at both groups (remembering that they have overlapping membership) as objectively and analytically as possible. While there is insufficient space here to conduct a detailed analysis of these industries, this appendix seeks to provide a simple summary of their economic status using the same geographic categories and economic variables that have been used throughout this study for the analysis of the biobusiness technology industries.

As is the case with biobusiness technology industries, the NAICS classification system does not perfectly capture the subject matter of the *bio production and processing industries*. Nevertheless, as the majority of the economic activities in the domain of the *bio production and processing industries* have a long pedigree (agriculture, for example, being one of the oldest of the organized economic activities of human beings), the NAICS system is arguably more robust, on the whole, as a system for organizing information related to these industries than it is for the other areas of biobusiness.

The NAICS codes that have been employed in assembling the data summarized in this appendix cover the following industry categories, at the two-digit, three-digit and six-digit levels:

NAICS 11:	<i>Agriculture, forestry, fishing and hunting</i>
NAICS 311:	<i>Food manufacturing</i>

---

<i>NAICS 312:</i>	<i>Beverage and tobacco product manufacturing</i>
<i>NAICS 316:</i>	<i>Leather and allied product manufacturing</i>
<i>NAICS 321:</i>	<i>Wood product manufacturing</i>
<i>NAICS 322:</i>	<i>Paper manufacturing</i>
<i>NAICS 325191:</i>	<i>Gum and wood chemical manufacturing</i>
<i>NAICS 325193:</i>	<i>Ethyl alcohol manufacturing</i>
<i>NAICS 325221:</i>	<i>Cellulosic organic fiber manufacturing</i>

Two of the above codes (*NAICS 325193* and *NAICS 325221*) were included explicitly as part of the selection of NAICS classifications chosen to act as proxies for the biobusiness technology industries for the analysis in the main body of this report. Two six-digit NAICS codes not explicitly listed here (*NAICS 31212 Breweries* and *NAICS 31213 Wineries*) are nevertheless included here in the data as part of the generic three-digit NAICS code, *312 Beverage and tobacco product manufacturing*. Likewise, three other six-digit NAICS codes not explicitly listed here (*NAICS 311221 Wet corn milling*, *NAICS 311222 Soybean processing* and *NAICS 311223 Other oilseed processing*) are also included here in the data as part of the generic three-digit NAICS code, *311 Food manufacturing*, along with many other six-digit NAICS codes.<sup>22</sup>

As revealed in Figure 36, the *bio production and processing industries* are responsible for directly employing significantly more than one quarter of a million people geographically located in Minnesota; and, as revealed in Figures 38 and 40, those jobs are housed within over 82,000 enterprises (including both farms and manufacturing/processing establishments) that together generate over \$650 billion each year in revenue for the state.

While almost all of the eleven states covered by this report, including Minnesota, experienced either static employment levels or slight loss of employment in the *bio production and processing industries* over the five years to the time of the most recent censuses, Figure 37 shows that Minnesota remained very competitive from the beginning to the end of the period. In fact, from 2002 to 2007 Minnesota improved its competitive position slightly as a location for employment in the *bio production and processing industries*, taking in account the size of the *bio production and processing* economy nationwide and the relative size of Minnesota's total economy to that of the nation as a whole. In short, all things being equal, Minnesota (with an employment density index of 1.53) performs much better than one would expect for a state the size of Minnesota.<sup>23</sup>

---

<sup>22</sup> All results reported in Appendix 5 were produced by Dr. Kelvin W. Willoughby, based on calculations using data taken from the U.S. Economic Census of 2002 and 2007 and the U.S. Census of Agriculture of 2002 and 2007. All industries within the two-digit generic NAICS Code 11 ("*NAICS 11 Agriculture, forestry, fishing and hunting*", which includes all NAICS codes at the three-digit level and lower, down to six-digit) are covered by the Census of Agriculture, which is conducted every five years by the U.S. Department of Agriculture, National Agricultural Statistics Service; whereas all industries within NAICS codes at levels high than the two-digit generic ("sector") level 11 (i.e., NAICS 21 and above) are covered by the Economic Census, which is conducted every five years by the U.S. Bureau of the Census. Thus, the data reported here (for 2002 and 2007) come from four separate censuses, conducted by two separate U.S. Government agencies.

<sup>23</sup> For a full explanation of the meaning of industry density indices, including the employment density index referred to here, see Appendix 4 of this report.

Figure 36: *Employment, Bio Production and Processing Industries, 2002-2007*

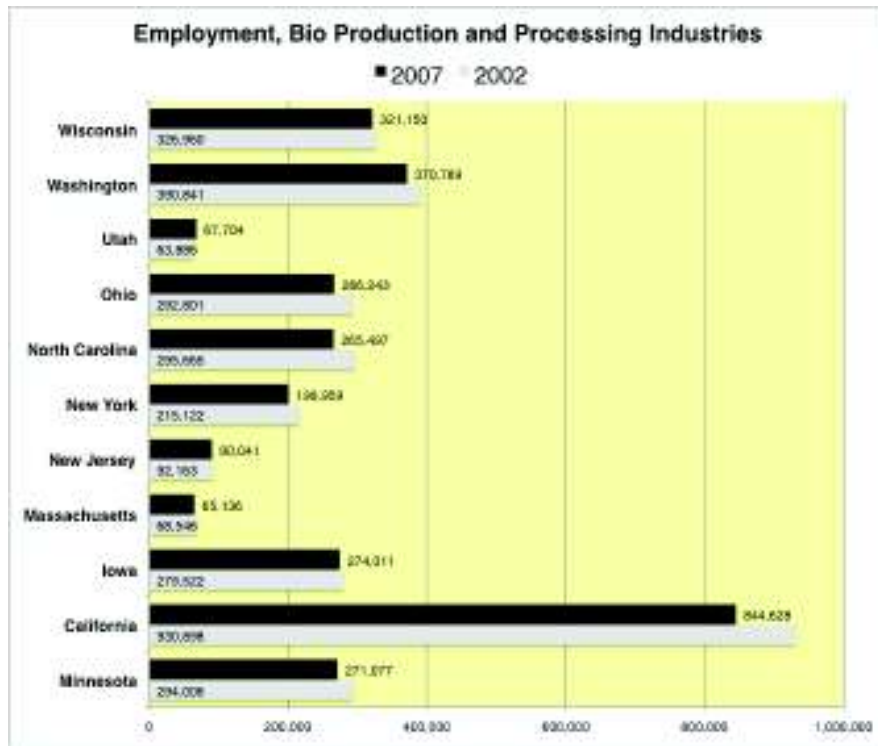


Figure 37: *Employment Density Indices, Bio Production and Processing Industries, 2002-2007*

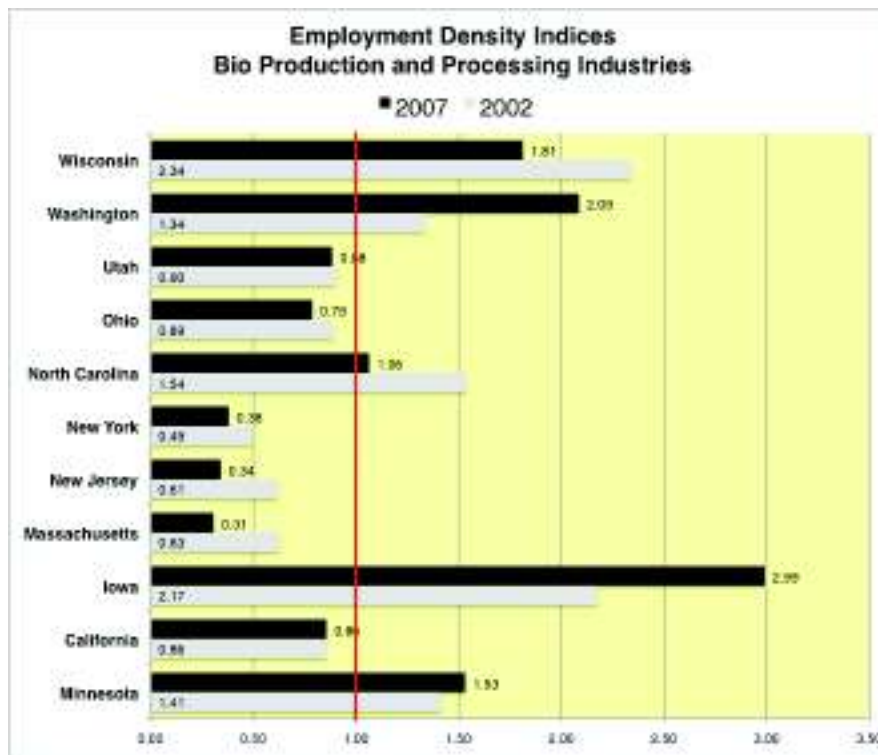


Figure 38 shows that none of the eleven states covered by this study experienced a dramatic shift in the number of *bio production and processing* enterprises domiciled in their respective geographical territory during the five years in question. Minnesota exhibited almost no perceptible net change during the period in its number of *bio production and processing* enterprises; and, as Figure 39 illustrates, Minnesota's competitiveness within the United States as a location for *bio production and processing* enterprises remained static at either end of the five-year period. However, as is also revealed by the results in Figure 39, Minnesota scored an enterprise density index for of about 2.0 for both 2002 and 2007, which means that Minnesota has remained consistently highly competitive (in fact, twice as competitive as is "normal" for U.S. states!) for the *bio production and processing industries*.

Figures 37 and 39 together also reveal that, despite California's enormous size in the *bio production and processing industries*, Minnesota is significantly more productive than California, overall, in generating both jobs and businesses in those industries. Minnesota appears to be challenged only by Iowa and Wisconsin in its productivity in generating *bio production and processing* enterprises. Interestingly, however, in addition to the established competition from Iowa and Wisconsin, Minnesota also appears to have been challenged recently by Washington state, which appears to be a rising star *vis-à-vis* its productivity in generating *bio production and processing* employment.

Figure 40 summarizes the aggregate annual income generated by the *bio production and processing* enterprises of each of the eleven competitor states at the beginning and end of the five-year period covered by the data. During that period Minnesota more than doubled the dollar-value of the revenue earned by its *bio production and processing* enterprises, maintaining its position as number three behind California and Iowa. While California is clearly the national leader—in terms of absolute size and the volume of business—Minnesota's position *vis-à-vis* California is remarkable. Minnesota has roughly only 14% of the population of California, yet the number of people employed in the *bio production and processing industries* of Minnesota is almost one third that of California; and the amount of income generated by Minnesota's *bio production and processing* enterprises is about 71% that of California's enterprises in the same industries.

The remarkable position of Minnesota as a location for business in the *bio production and processing industries* is illustrated even more powerfully in Figure 41, in which Minnesota's enterprises (with an aggregate revenue density index of 3.52) are seen to be several times more "productive" than California's enterprises (with an aggregate revenue density index of 0.79) in generating revenue from their respective *bio production and processing industries*. In short, relatively speaking, Minnesota's *bio production and processing* enterprises make more money than those of their cousins in California (when the numbers are weighted to take in to account the relative sizes of the economies of the two states and the scale of the pertinent industries nationwide). One possible explanation for this is that Minnesota's *bio production and processing* enterprises tend, on average, to be more active outside the geographic boundaries of their home state than is the norm for their cousins both in California and throughout rest of the nation. In other words, Minnesota tends—more than is usually the case—to be the home for *bio production and processing* enterprises with a broad national and international sweep to their business.

Figure 38: Enterprises, Bio Production and Processing Industries, 2002-2007

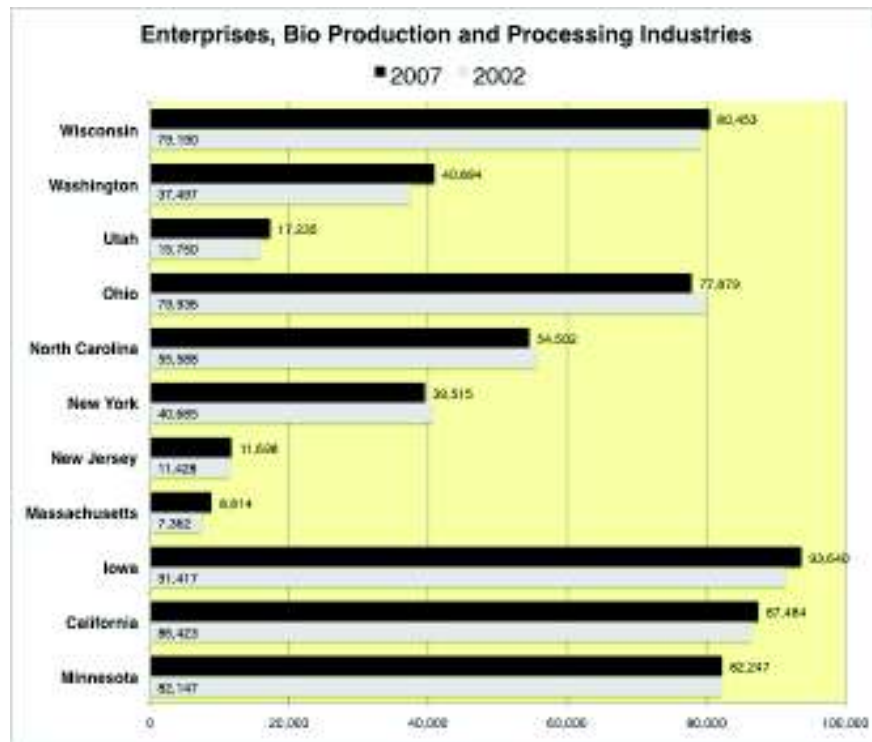


Figure 39: Enterprise Density Indices, Bio Production and Processing Industries, 2002-2007

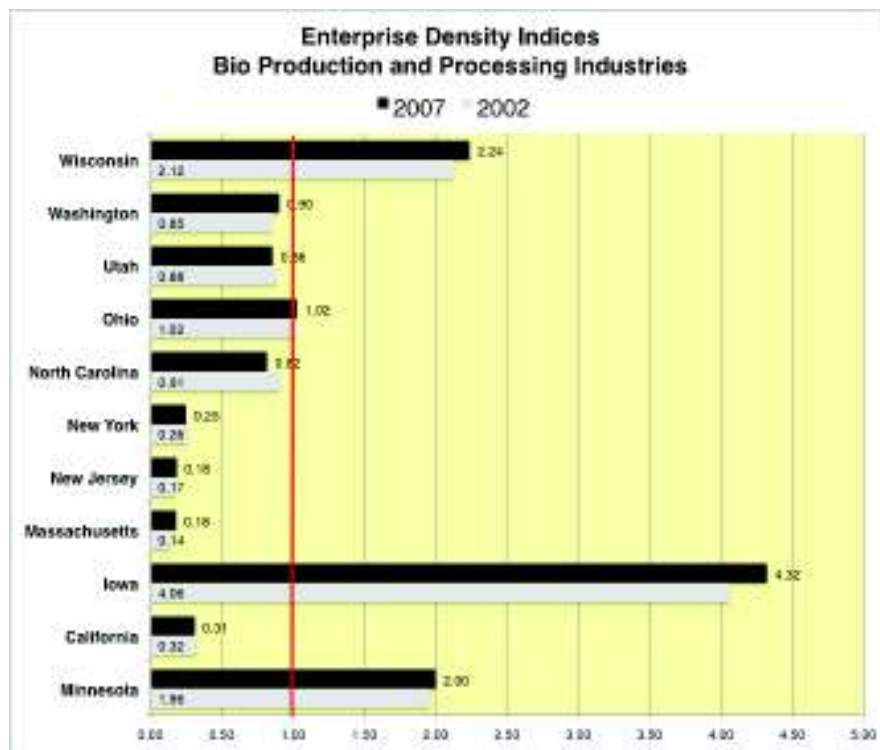




Figure 40: Revenue, Bio Production and Processing Industries, 2002-2007

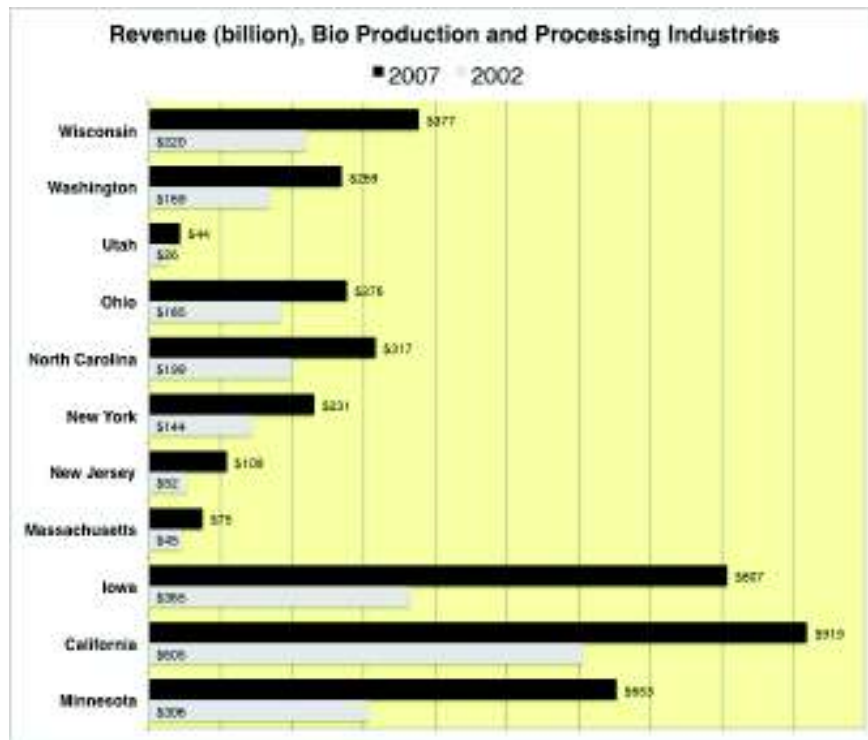


Figure 41: Revenue Density Indices, Bio Production and Processing Industries, 2002-2007

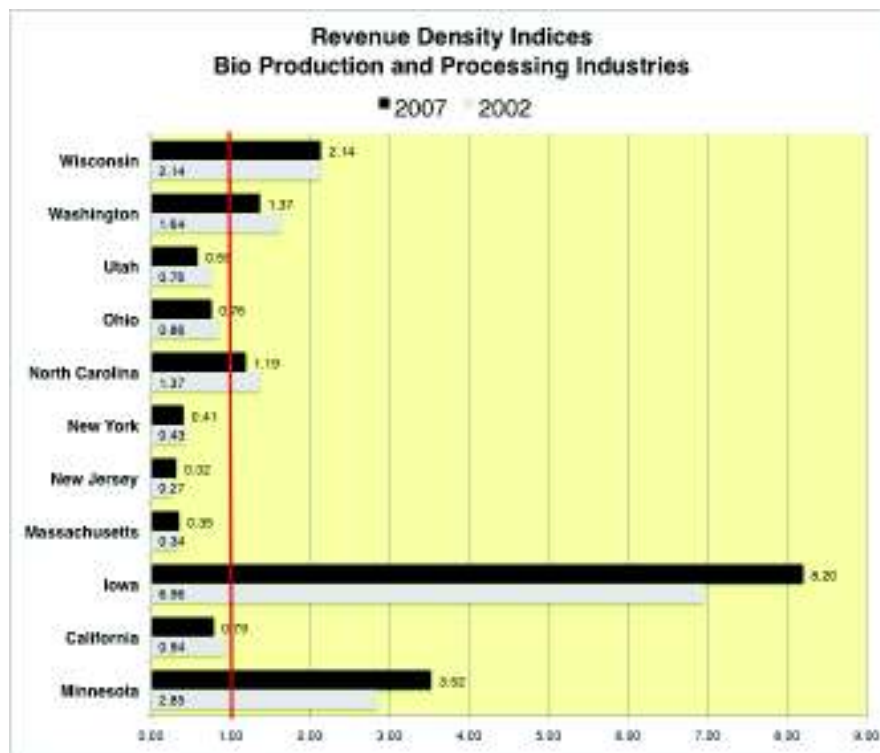




Figure 42: *Percentage Change in Employment Density Index, Bio Production & Processing Industries, 2002-2007*

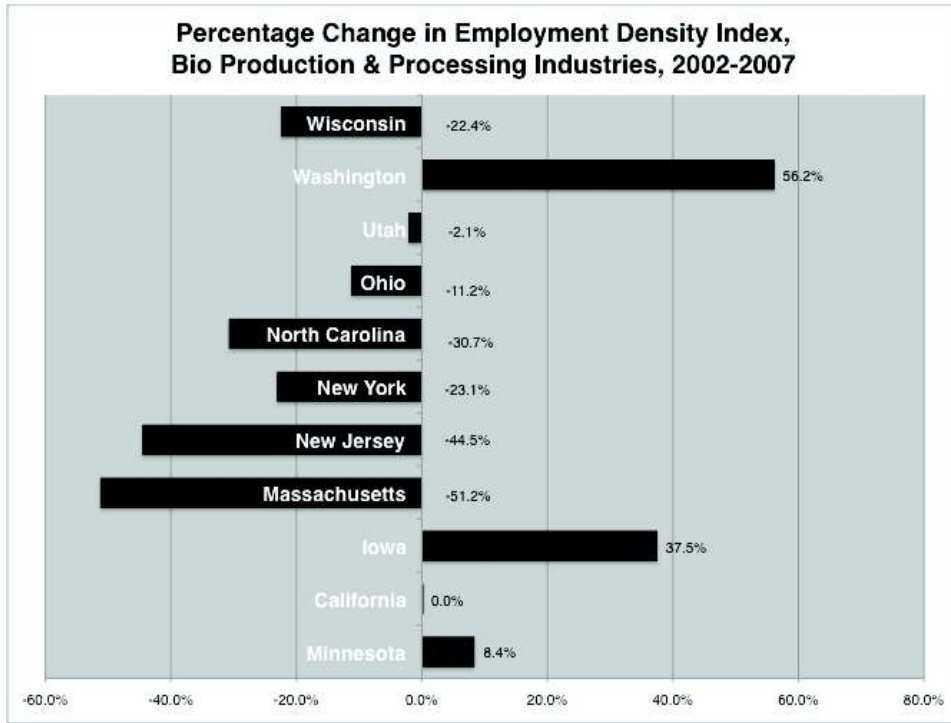
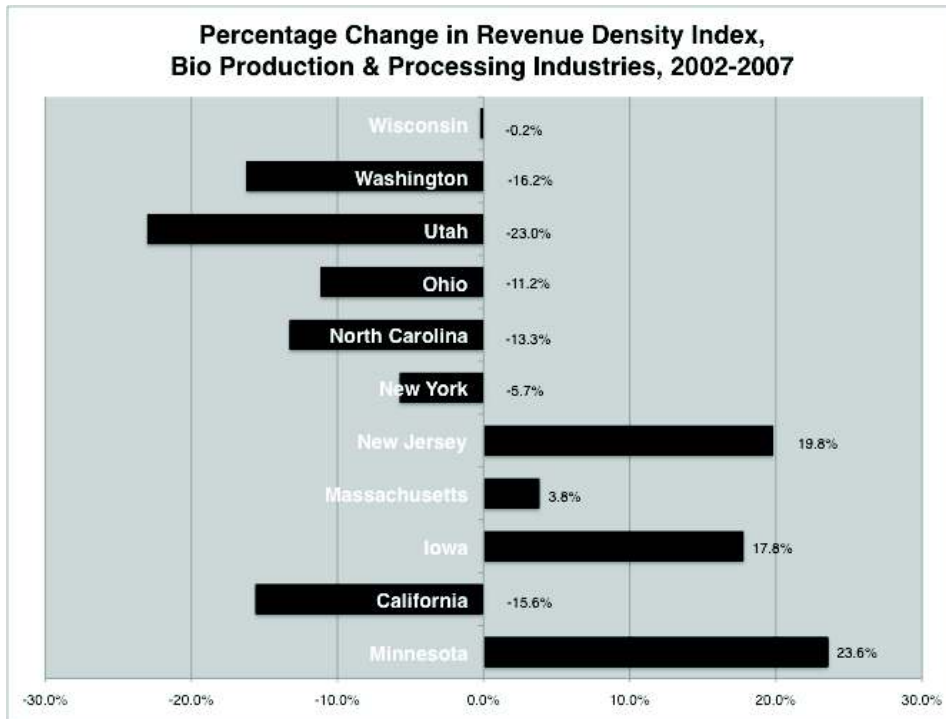


Figure 43: *Percentage Change in Revenue Density Index, Bio Production & Processing Industries, 2002-2007*



Figures 36 and 40 taken together are evocative in at least one other respect. They show that—not only in Minnesota, but also throughout the eleven competitor states—during the five years to 2007 the *bio production and processing industries* enjoyed business growth (i.e., financial growth) without enjoying corresponding local employment growth. In addition, as is revealed by Figures 38 and 39, the business growth of that period was accomplished without a net increase in the number of locally based enterprises in the relevant industries. In brief, from 2002 to 2007, the *bio production and processing industries* of Minnesota and the other states appear to have improved their overall economic performance through prudent business strategies and expanding the global sweep of their activities, but without adding to the net level of local employment or local enterprise creation in *bio production and processing* within their home states.

Figures 42 and 43 enable us to observe—in a very dynamic way—changes in the competitive position of Minnesota and the other states over time in the *bio production and processing industries*, by examining changes in selected industry density indices between 2002 and 2007. Figure 42 does this for employment density indices and Figure 43 does this for revenue density indices. Figures 42 and 43 take the same data that were used to calculate the employment density indices in Figure 37 and the revenue density indices in Figure 41 but express the results as a percentage change over five years from the base position of the respective indices for each state at the beginning of the respective period. These two graphs may be useful for helping state leaders to identify which states might be doing “something right” to improve their competitive position in the *bio production and processing industries* and which states might be “getting behind in the game.” As we observed during similar analysis we conducted for the various biobusiness technology industries analyzed earlier in this report, the states positioned on the right hand side of each graph are improving their game, while the states positioned on the left hand side of each graph may need to readjust their game plans.

The most impressive feature of the information in these Figures is the outstanding performance of Minnesota as the most improved state in terms of its dynamic propensity for generating revenue through locally based enterprises in the *bio production and processing industries*. Minnesota's prowess is followed by that of New Jersey and Iowa. Interestingly, Massachusetts—which, overall, is a minor player in the *bio production and processing industries*—noticeably improved its performance as a location for earning money through these industries.

Figure 42 shows that Minnesota improved its relative position as a productive place for generating employment in the *bio production and processing industries* over the five-year period in question, although both Washington and Iowa both lifted their game very impressively (relatively speaking) in this regard.

To conclude, Minnesota is a major player within the United States in the *bio production and processing industries*. Significant employment and revenue are generated for Minnesota through the activities of its locally based *bio production and processing* enterprises which, according to the evidence at hand, are remarkably active outside the state on the national and international scene. In addition, Minnesota appears to have been improving its competitiveness in the *bio production and processing industries* during recent years despite lack of growth in the *bio production and processing* jobs located within the state.

## *List of Figures*

- Figure 1: Biobusiness Technology Employment as a Percentage of Employment in All Industries—United States and Minnesota, 1997, 2002 & 2007  
*(also Executive Summary—Figure 1)*
- Figure 2A: Percentage of Total Biobusiness Technology Employment in Each Industry—United States and Minnesota, 2007
- Figure 2B: Percentage of Total Biobusiness Technology Employment in Each Industry—United States and Minnesota, 2002
- Figure 2C: Percentage of Total Biobusiness Technology Employment in Each Industry—United States and Minnesota, 1997
- Figure 3: Biobusiness Technology Industries in Minnesota, Total Number of Employed People, 1997-2007  
*(also Executive Summary—Figure 2)*
- Figure 4: Biobusiness Technology Industries (Map of NAICS-based categories - 2007)
- Figure 5: Employment, Biobusiness Technology Industries—1997, 2002 & 2007
- Figure 6: Percentage of Total National Employment in Biobusiness Technology Industries—1997, 2002 & 2007
- Figure 7: Enterprises, Biobusiness Technology Industries—1997, 2002 & 2007
- Figure 8: Employment Density Indices, Biobusiness Technology Industries—1997, 2002 & 2007
- Figure 9: Enterprise Density Indices, Biobusiness Technology Industries—1997, 2002 & 2007
- Figure 10A: Percentage Change in Employment Density Indices, 1997-2002, Biobusiness Technology Industries
- Figure 10B: Percentage Change in Employment Density Indices, 2002-2007, Biobusiness Technology Industries
- Figure 11: Employment, Medical Devices Industry—1997, 2002 & 2007
- Figure 12: Percentage of Total National Employment in Biobusiness Technology Industries—1997, 2002 & 2007
- Figure 13: Enterprises, Medical Devices Industry—1997, 2002 & 2007
- Figure 14: Employment Density Indices, Medical Devices Industry—1997, 2002 & 2007
- Figure 15: Enterprise Density Indices, Medical Devices Industry—1997, 2002 & 2007
- Figure 16A: Percentage Change in Employment Density Indices, 1997-2002, Medical Devices Industry

- 
- Figure 16B: Percentage Change in Employment Density Indices, 2002-2007, Medical Devices Industry
- Figure 17: Employment, R&D in the Life Sciences—1997, 2002 & 2007
- Figure 18: Percentage of Total National Employment, R&D in the Life Sciences—1997, 2002 & 2007
- Figure 19: Enterprises, R&D in the Life Sciences—1997, 2002 & 2007
- Figure 20: Employment Density Indices, R&D in the Life Sciences—1997, 2002 & 2007
- Figure 21: Enterprise Density Indices, R&D in the Life Sciences—1997, 2002 & 2007
- Figure 22A: Percentage Change in Employment Density Indices, 1997-2002, R&D in the Life Sciences
- Figure 22B: Percentage Change in Employment Density Indices, 2002-2007, R&D in the Life Sciences
- Figure 23: Employment, Agri-bio & Bio-industrial Industries—1997, 2002 & 2007
- Figure 24: Percentage of Total National Employment in Agri-bio & Bio-industrial Industries—1997, 2002 & 2007
- Figure 25: Enterprises, Agri-bio & Bio-industrial Industries—1997, 2002 & 2007
- Figure 26: Employment Density Indices, Agri-bio & Bio-industrial Industries—1997, 2002 & 2007
- Figure 27: Enterprise Density Indices, Agri-bio & Bio-industrial Industries—1997, 2002 & 2007
- Figure 28: Employment, Pharmaceuticals Industry—1997, 2002 & 2007
- Figure 29: Percentage of Total National Employment in the Pharmaceuticals Industry—1997, 2002 & 2007
- Figure 30: Enterprises, Pharmaceuticals Industry—1997, 2002 & 2007
- Figure 31: Employment Density Indices, Pharmaceuticals Industry—1997, 2002 & 2007
- Figure 32: Enterprise Density Indices, Pharmaceuticals Industry—1997, 2002 & 2007
- Figure 33A: Percentage Change in Employment Density Indices, 1997-2002, Pharmaceuticals Industry
- Figure 33B: Percentage Change in Employment Density Indices, 2002-2007, Pharmaceuticals Industry
- Figure 34: Overall Economic Trends, Biobusiness Technology Industries (and the Macro-economy) 2002- 2007  
(also *Executive Summary—Figure 3*)

- 
- Figure 35: Fields of Biobusiness: Biological Technology  
*(Appendix 1)*
- Figure 36: Employment, Bio Production and Processing Industries, 2002-2007  
*(Appendix 5)*
- Figure 37: Employment Density Indices, Bio Production and Processing Industries, 2002-2007  
*(Appendix 5)*
- Figure 38: Enterprises, Bio Production and Processing Industries, 2002-2007  
*(Appendix 5)*
- Figure 39: Enterprise Density Indices, Bio Production and Processing Industries, 2002-2007  
*(Appendix 5)*
- Figure 40: Revenue, Bio Production and Processing Industries, 2002-2007  
*(Appendix 5)*
- Figure 41: Revenue Density Indices, Bio Production and Processing Industries, 2002-2007  
*(Appendix 5)*
- Figure 42: Percentage Change in Employment Density Index, Bio Production & Processing Industries, 2002-2007  
*(Appendix 5)*
- Figure 43: Percentage Change in Revenue Density Index, Bio Production & Processing Industries, 2002-2007  
*(Appendix 5)*