Surveying Minnesota's Science and Technology Landscape

November 2015

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CONTENTS

Executive Summary

The goal of the Minnesota High Tech Association (MHTA) is to help Minnesota become one of the nation's top five science and technology states. This report aims to identify and assess Minnesota's strengths as they relate to science, technology, and innovation in order to better identify synergies and opportunities for collaboration between various high-tech industries.

Minnesota has long been known as Medical Alley, but there are a handful of other sectors shaping Minnesota's economy. This report briefly examines Minnesota's employment trends in its high-tech economy, and provides a more detailed analysis of the types of patents issued in Minnesota and to which entities. Between 2010 and 2014, the top five patent grantees (including individuals) accounted for 38.6 percent of all patents issued in Minnesota, with medical devices, data processing, information storage and biotechnology categories accounting for the ten most predominate classes for which patents were issued to Minnesota entities.

The report then examines Minnesota's rankings with respect to science, technology, and innovation across three sets of rankings compiled by three organizations: Information Technology and Innovation Foundation (ITIF), Milken Institute, and Bloomberg. Despite the differences among the ranking methodologies, a couple of trends emerge. Minnesota has relatively high rankings with respect to three key categories: (1) digital connectedness; (2) workforce; and (3) patents. On the other hand, Minnesota does not rank as high with respect to characteristics related to R&D inputs/expenditures and economic dynamism.

Examining startup financing in Minnesota, the report notes that, since the Great Recession, much of the venture capital in Minnesota has gone to three industries: medical devices, software, and biotechnology. A similar trend is found in investments by angel investors. These industries reflect not only the areas in which new businesses are growing but also Minnesota's historical strengths.

Further, Minnesota's only research university, the University of Minnesota, is home to a number of strong research organizations and graduate programs. Examining rankings by *U.S. News & World Reports*, the report notes that the University of Minnesota has three graduate programs ranked in the top ten in the nation: chemical engineering, applied mathematics, and combinatorics/discrete mathematics. These programs, together with key research initiatives identified by the university through Minnesota's Discovery, Research, and InnoVation Economy (MnDRIVE), and the Institute for Mathematics and its Applications, could lead to the development and potential commercialization of innovative products. By focusing on Minnesota's historical strengths in the medical device industry, in conjunction with current and potential future industry trends, the University of Minnesota, in partnership with industry, could be well-positioned to develop novel, innovative technologies.

Building on Minnesota's commercial strengths in medical device, software, and biotechnology, together with its academic strengths in mathematics and chemical engineering is key to helping enhance Minnesota's innovation competitiveness. Fostering an environment of collaboration between these key industries and academic research areas offers the most fruitful opportunities for technology advancement and innovation.

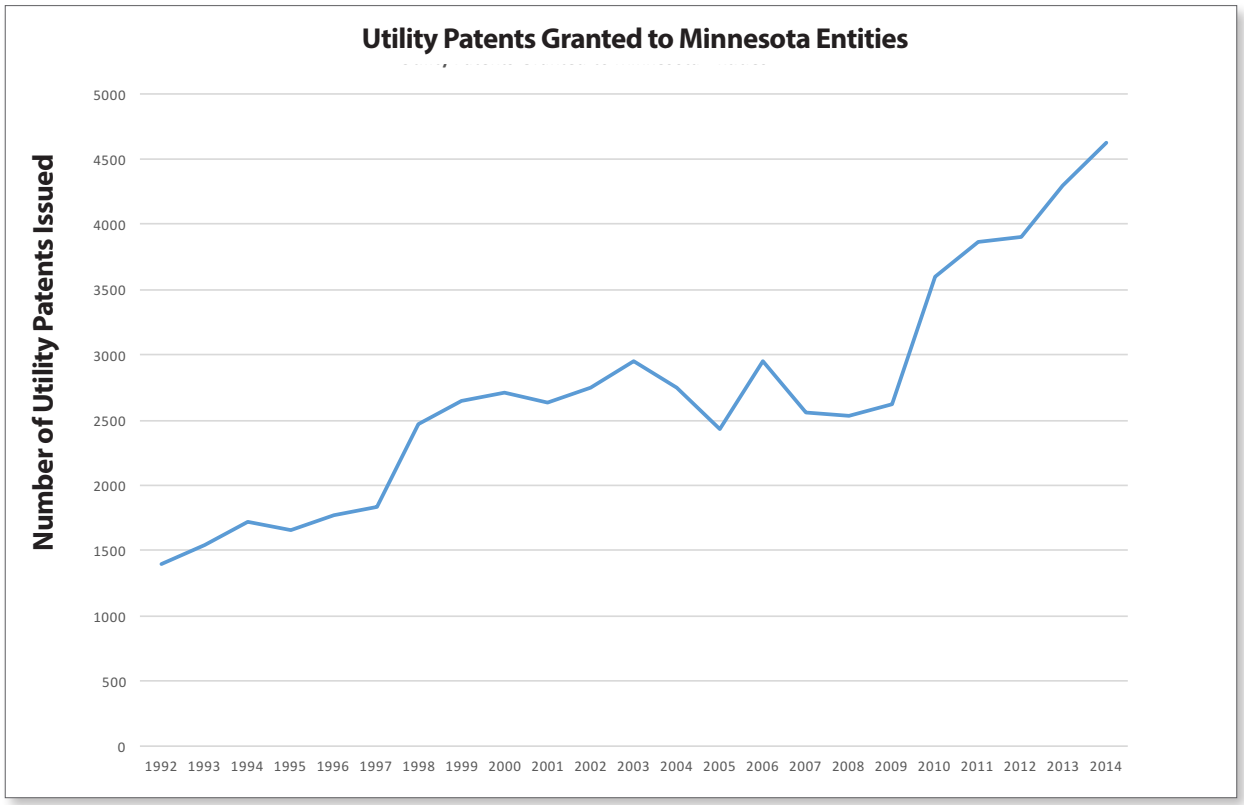
1. Introduction

The goal of the Minnesota High Tech Association (MHTA) is to help Minnesota become one of the nation's top five science and technology states. Indeed, CNBC recently ranked Minnesota as the best state in the nation to do business.[1] However, with a diverse state economy and a growing high-tech startup community, how can Minnesota better position itself as a leader in science, technology, and innovation? In order to answer this question, we must first assess Minnesota's science and technology landscape, identifying strengths, weaknesses, and opportunities for growth.

The following, which is not exhaustive, examines Minnesota's science and technology community from a variety of perspectives. Section 2 provides an overview of Minnesota's employment and patent trends in the high tech industry. Section 3 provides an overview of how Minnesota fares in terms of innovation with respect to other states. Section 4 explores financing of Minnesota's technology startups. Section 5 examines the University of Minnesota, including some of the nation's top graduate programs and other University research initiatives. Section 6 concludes the discussion.

2. Minnesota High Tech Industry Trends

According to the Technology Councils of North America (TECNA), Minnesota has 9,023 technology companies, with an estimated payroll of $12.3 billion.[2] Minnesota has the nation's 17th highest employment levels in the high tech industry, employing 136,800 people in 2014. This figure, however, does not include 38,000 employees in the medical device space nor the 48,000 employees in the biotech space. Including, these figures brings Minnesota's high tech and closely related biosciences employment to 222,800. There are another 151,800 employees working in "tech occupations," which includes high tech jobs across all industries, such as banking, finance, and retail.



Minnesota is also home to some of the nation's most innovative companies, such as 3M and Medtronic. These companies, along with many more, contribute to Minnesota's innovation economy, which more than tripled the number of patents granted between 1992 and 2014, from 1,396 to 4,626.[3] Indeed, some of Minnesota's and the nation's most well-known companies top the list for patents granted between 2010 and 2014, with 2,223 patents granted to IBM during this time period.[4]

Top Ten Minnesota Entities to Receive Patents (2010-2014)

First-Named Assignee	2010	2011	2012	2013	2014	Total
IBM	424	439	451	448	461	2223
Medtronic, Inc.[5]	286	266	322	346	368	1588
3M Innovative Properties Company	315	297	241	302	320	1475
Cardiac Pacemakers, Inc.	200	265	240	285	288	1278
Individually Owned Patent[6]	220	247	234	264	295	1260
Honeywell International, Inc.	199	179	191	159	178	906
Seagate Technology, LLC	83	157	172	180	201	793
Boston Scientific Scimed, Inc.	139	144	139	112	95	629
ADC Telecommunications, Inc.	113	90	86	86	71	446
Ecolab USA Inc.	5	38	65	64	84	256

Medtronic, 3M Innovative Properties Company, Cardiac Pacemakers, Inc., and individual-owned patents, round out the top five grantees, with 1,588; 1,475; 1,278; and 1,260, respectively. These companies and individuals are some of the most innovative in Minnesota, and represent the IT, medical devices, and telecommunications industries.

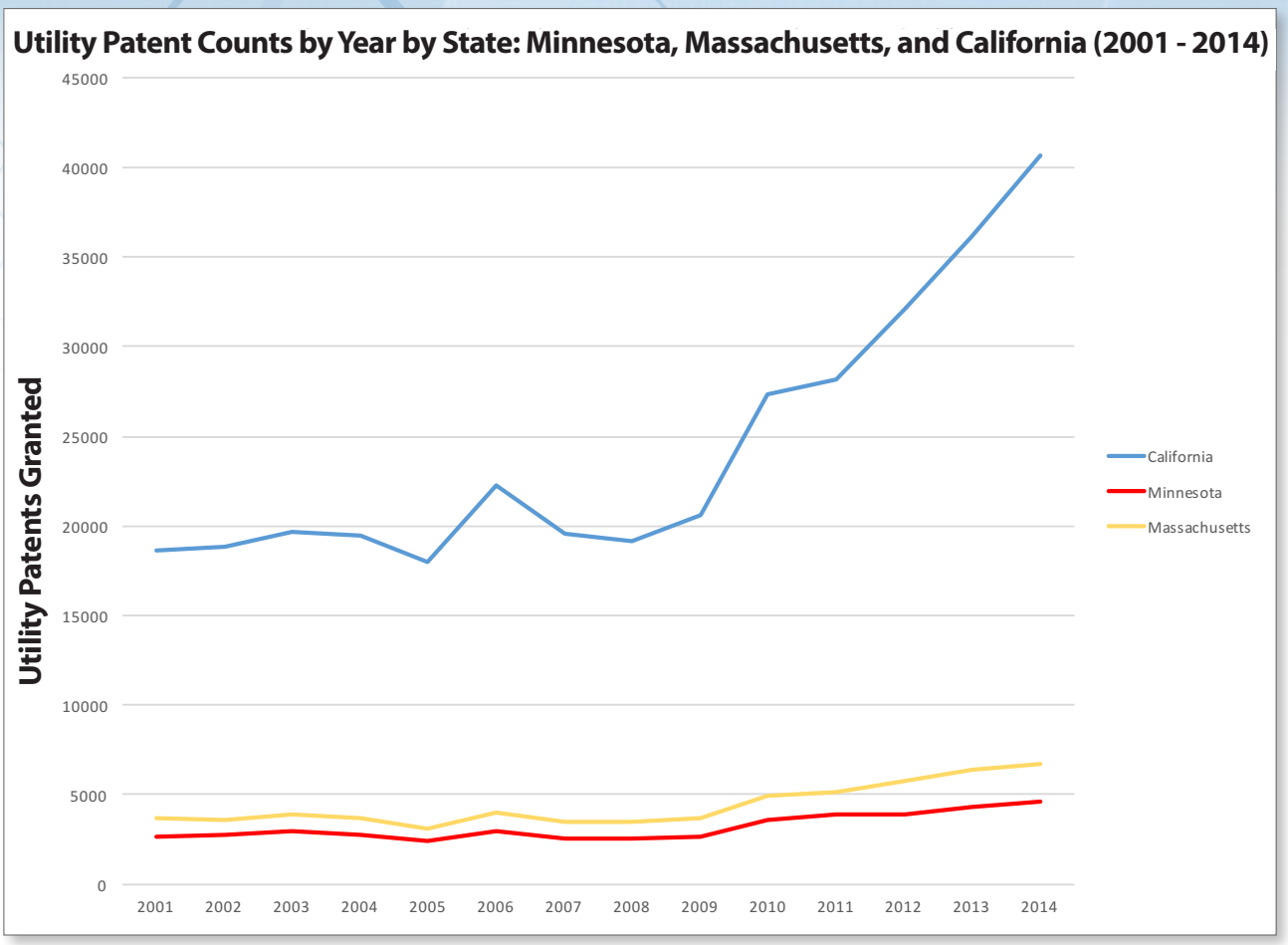
Of the 20,277 patents granted to Minnesota companies between 2010 and 2014, more than 10 percent were issued to IBM. Medtronic accounted for 7.8 percent of the patents, and 3M accounted for 7.3 percent. Together, the top five patent grantees (including individuals), accounted for 38.6 percent of all patents issued in Minnesota.

Of the patents issued in Minnesota between 2010 and 2014, those related to the light, thermal, and electrical surgical applications were most prevalent, totaling 2,095. In fact, patents related to surgery account for four of the top five classes in which patents were granted. Such a preponderance of patents related to surgical applications is not surprising, as Minnesota is home to many medical device companies. Data processing, information storage, and biotechnology are the other general patent categories that compose the ten most predominate classes for which patents were issued to Minnesota entities.

Top Ten Minnesota Patents Issued by Technology Class (2010-2014)[7]

Rank	Class Title	2010	2011	2012	2013	2014	Total
1	Surgery: Light, Thermal, and Electrical Application	349	362	391	483	510	2095
2	Surgery (includes Class 600)	150	206	208	247	266	1077
3	Surgery (instruments)	116	120	139	141	172	688
4	Surgery (Medicators and Receptors)	102	109	137	142	131	621
5	DP: Database and File Management or Data Structures (Data Processing)	112	124	144	112	106	598
6	Multicellular Living Organisms and Unmodified Parts Thereof and Related Processes	82	68	113	128	175	566
7	Drug, Bio-Affecting and Body Treating Compositions (includes Class 514)	61	106	102	104	120	493
8	Dynamic Magnetic Information Storage or Retrieval	57	61	62	75	163	418
9	Prosthesis (i.e., Artificial Body Members), Parts Thereof, or Aids and Accessories Therefor	57	91	73	89	89	399
10	DP: Financial, Business Practice, Management, or Cost/Price Determination (Data Processing)	68	67	87	85	60	367

As Minnesota and other states throughout the country continue to recover from the Great Recession, the number of patents issued in Minnesota between 2008 and 2014 has steadily risen since 2009, and tracks closely the fluctuations in issuance of patents to entities in Massachusetts.[8] California, on the other hand, exceeds by an order of magnitude, patent rates for both Minnesota and Massachusetts. Additionally, the fluctuations in patents issued to California entities does not follow that of patents issued to Minnesota or Massachusetts entities. Most notable is the degree to which the issuance of patents accelerates between 2011 and 2014. Indeed, over this time period, California experienced a 44.5 percent increase in the number of patents issued, whereas Minnesota and Massachusetts experienced increases of 19.8 percent and 29.6 percent, respectively.



3. Innovation: How Minnesota Compares

As with any goal, helping make Minnesota a top five state in terms of science and technology requires a benchmark from which comparisons can be made. While there are a number of rankings available, to get a better handle on where Minnesota sits with respect to other states in terms of science and technology, we shall consider three different rankings, those compiled by: Information Technology and Innovation Foundation (ITIF); Milken Institute; and Bloomberg News.

For each source, the rankings provide a numerical composite score for each state based on a number of criteria or categories. While there is some similarity between categories and criteria, one source of ranking does not depend on that of the others. By comparing different sources, the aim is to identify commonalities between rankings, and thereby identify "drivers" of innovation. Before moving on, we first compare the top five states across sources of ranking. This comparison helps to illustrate the variability between ranking methodologies.

Despite the differences in methodologies, Massachusetts captures the top spot in two of the three rankings, and is ranked third in the other. Indeed, California and Massachusetts are ranked among the top five states across all three rankings, and Washington and Maryland are ranked in the top five in two of the three rankings.

Top Five Science and Technology States

Ranking	2014 ITIF Ranking	2014 Milken Institute Ranking	2013 Bloomberg Ranking
1	Massachusetts	Massachusetts	Washington
2	Delaware	Maryland	California
3	California	California	Massachusetts
4	Washington	Colorado	Connecticut
5	Maryland	Utah	Oregon

3.1 ITIF's Rankings

To begin, we first consider the rankings published by ITIF in 2014.[9] The report scores states on 25 criteria, weighting the scores and compiling them to form a composite or overall score. ITIF's ranking is based on five categories: *Knowledge Jobs, Globalization, Economic Dynamism, Digital Economy,* and *Innovation Capacity*. The categories are composed of a number of metrics and are aggregated to determine the *Overall* score.

ITIF

Category	MN 2014 Ranking	Top State
Overall	13	Massachusetts
Knowledge Jobs	8	Massachusetts
Globalization	34	Delaware
Economic Dynamism	30	Utah
Digital Economy	2	Massachusetts
Innovation Capacity	13	Washington

The 2014 report ranks Minnesota 13 out 50 states in terms of overall innovation competitiveness, behind states such as Massachusetts, California and Washington. Digging into the categories that make up the overall ranking, we see that Minnesota ranks eighth in terms of *knowledge Jobs*, where Massachusetts takes the top spot. Minnesota ranks 34th and 30th in terms of *Globalization* and *Economic Dynamism*, respectively, with Delaware and Utah taking the top respective spots. Just behind Massachusetts, Minnesota ranks second with respect to *Digital Economy*, and 13th with respect to *Innovation Capacity*. Washington State leads in this category.

Exploring in more detail some of the sub-categories that make up the rankings, Minnesota ranks in the top 10 in a number of categories: *Information Technology Jobs, Workforce Education, High-Wage Traded Services, Inventor Patents, E-Government, Broadband Telecommunications, Health IT, Scientists and Engineers,* and *Venture Capital*. While the following does not examine each of these in detail, the rankings do suggest that Minnesota has a number of strong attributes when it comes to innovation and technology, particularly in *High-Wage Traded Services, E-Government*, and *Health IT*.

High-Wage Traded Services include jobs in the insurance and financial services sectors, as well as legal, publishing, and advertising. According to ITIF's report 13.7 percent of Minnesota's workforce is employed in a high-wage traded service sector, ranking below Delaware, New York, and Connecticut, yet well above the national average of 10.2 percent.

Minnesota also ranks in the top five in terms of *E-Government*, which measures the use of digital technology in state government. ITIF argues that state government's use of technology not only helps to make government more efficient but engenders a broader use of technology among its residents and businesses. Minnesota is tied for third with California, Ohio, Pennsylvania, Tennessee, and West Virginia, but behind Michigan and Utah.

Perhaps related to *E-Government*, Minnesota also ranks highly in terms of *Health IT*, which is a measure of electronically routing prescriptions and storing medical records. Minnesota's number two ranking, just behind Vermont, is driven by its leadership in mandating e-prescriptions. Of course, Minnesota is home to a number of insurance companies and medical device companies, and has a reputation for practicing "good government," all of which possibly contribute to Minnesota's superior ranking in this category.

While Minnesota is a leader in a number of areas, there is still room for improvement in other areas. For example, Minnesota ranks poorly in terms of *Immigration of Knowledge Workers, Export Focus of Manufacturing and Services, Foreign Direct Investment, Job Churning, Initial Public Offerings, Entrepreneurial Activity,* and *Non-Industry Investment in R&D*. Particularly discouraging is Minnesota's ranking, at 48 out of 50, in terms of *Entrepreneurial Activity*. The ranking, based on the Kauffman Foundation's 2011 and 2012 entrepreneurship index, measures the percentage of individuals starting new businesses in the state. According to the report, between 2011 and 2012, 0.19 percent of Minnesotans started a new business — this puts Minnesota well behind both the leading state, Vermont (0.46 percent), and the national average of 0.30 percent. The Kauffman Foundation's methodology is not particular to science and technology business formation, but includes all new businesses.

3.2 Milken Institute's Rankings

Next, consider the rankings published by the Milken Institute in 2014.[10] The report scores states on 78 indicators, compiled into five composite scores which are used to determine an overall score. The composite scores are: *Research and Development Inputs, Risk Capital and Entrepreneurial Infrastructure, Human Capital Investment, Technology and Science Workforce,* and *Technology Concentration and Dynamism.*[11]

Milken Institute

Category	MN 2014 Ranking	Top State
Overall	12	Massachusetts
R&D Inputs	24	Massachusetts
Risk Capital & Entrepreneurial Infrastructure	11	Massachusetts
Human Capital Investment	4	Massachusetts
Technology and Science Workforce	7	Massachusetts
Technology Concentration and Dynamism	20	Utah

The 2014 report by the Milken Institute ranks Minnesota 12 out of 50 states in terms of science and technology, with Massachusetts ranking first overall. Exploring the composite scores in a bit more depth, Massachusetts takes the top spot in all categories, with the exception of *Technology Concentration and Dynamism* which goes to Utah.

Minnesota's strengths are focused on workforce and investments in human capital. Minnesota ranks in the top 10 with respect to *Human Capital Investment* and *Technology and Science Workforce,* at fourth and seventh, respectively. Not far behind is Minnesota's ranking of 11th with respect to *Risk Capital & Entrepreneurial Infrastructure*. However, Minnesota ranks 24th in terms of *Research and Development Inputs*, which includes R&D expenditures across a number of sciences, as well as federal, industry, and academic R&D per capita spending.

3.3 Bloomberg's Rankings

Finally, consider the report released by Bloomberg News in 2013.[12] The report scores states on seven criteria which are weighted to give an overall score on which states are ranked. The categories are: *STEM Professionals, Science and Technology Degrees, Utility Patents, State R&D Spending, Gross State Product per Employee, Three-year Change in Productivity,* and *Public Technology Companies as a Share of all Public Companies.* Unlike the rankings by ITIF or the Milken Institute, Bloomberg does not create composite scores. Rather, the scores for each category are aggregated to form the overall score.

Bloomberg

Category	MN 2013 Ranking	Top State
Overall	10	Washington
STEM Professionals	8	DC
Science & Tech Degrees	14	DC
Utility Patents	9	California
State R&D Spending	28	New York
GSP/Employee	21	DC
3-yr Change in Productivity	15	North Dakota
Public Tech Companies as Share of All Public Cos.	14	New Mexico

Bloomberg ranks Minnesota 10 out of 51 states and Washington, DC in terms of innovation. Of particular note are Minnesota's rankings with respect to *STEM Professionals* and *Utility Patents*. With a ranking of eighth, 2.7 percent of Minnesota's population are *STEM Professionals*; and with a ranking of ninth, Minnesota accounts for 3.23 percent of the nation's *Utility Patents*. Taking the top spot with respect to *STEM Professionals* is Washington, DC, with 9.23 percent of the District's population holding a STEM position. California ranks first in term of *Utility Patents*, accounting for 26.54 percent of nation's share of utility patents.

On the downside, Minnesota's spending on R&D ranks 28th, behind New York, Ohio, Florida, and California, each of which account for more than 10 percent of the nation's spending on R&D—that is, four states account for nearly 46 percent of the nation's R&D spending. Minnesota's share of R&D spending is 0.83 percent.

3.4 Summary

This section examined Minnesota's ranking with respect to innovation across surveys compiled by ITIF, the Milken Institute and Bloomberg. In no case did Minnesota rank higher than 10 (Bloomberg) or lower than 13 (ITIF) overall. Minnesota ranks particularly high (in the top 10) with respect to *Digital Economy* (ITIF); *Human Capital Investment* and *Technology and Science Workforce* (Milken Institute); and *STEM Professionals* and *Utility Patents* (Bloomberg). These categories represent Minnesota's current strengths as they relate to innovation competitiveness, and can be grouped into three general categories: (1) digital connectedness, (2) workforce, and (3) patents.

On the other hand, Minnesota does not rank as high with respect to characteristics related to R&D inputs/expenditures and economic dynamism. Minnesota ranks 34th and 30th in terms of *Globalization* and *Economic Dynamism*, respectively (ITIF); 24th in terms of *R&D Inputs* (Milken Institute); and 28th in terms of *State R&D Spending* (Bloomberg). The relatively low rankings with respect to globalization and economic dynamism are perhaps related to the relatively low investments in R&D.

Economic dynamism, for example, concerns the: (1) degree of job churning; (2) number of fast-growing firms; (3) number and value of IPOs; (4) number of entrepreneurs starting new businesses; and (5) number of individual patents granted. Without a strong investment—and outcome—in R&D, there will likely be fewer entrepreneurs doing research leading to patents, resulting in fewer new, fast-growing businesses and, in turn, fewer high-value IPOs.

Increasing Minnesota's competitiveness with respect to innovation will likely require greater investment in R&D activities as well as, perhaps, stronger incentives for Minnesota companies to expand abroad and for attracting foreign direct investment to the state. Minnesota should also build on its strengths, including continuing to develop—and retain—a talented STEM workforce while continuing to expand access to broadband for businesses, families, and institutions throughout the state.

4. Tech Startup Financing in Minnesota

Access to capital plays an important role in helping small, innovative technology companies expand and grow. Angel investors and venture capital firms are critical to providing startups with this capital. Indeed, three of the top five science and technology states, according to ITIF, also rank in the top five with respect to Venture Capital, where ITIF measures the amount of venture capital invested as a percentage of worker earnings. Massachusetts and California, for example, hold the first and second rankings, respectively, with venture capital investments accounting for 0.86 percent and 0.82 percent of each state's percentage of worker earnings. Below we examine angel investment and venture capital activity in Minnesota.

4.1 Venture Capital

Venture capital accounts for 0.10 percent of worker earnings in Minnesota, which ITIF ranks as tenth in the nation (ITIF). Venture capital plays a crucial role in helping young companies gain access to capital. The amount of venture capital flowing into Minnesota will continue to be a key indicator of the strength of Minnesota's startup economy.

While Minnesota has long been known as Medical Alley, which is reflected in investments from venture capitalists, there are a handful of other growing industries that are shaping Minnesota's economy. Based on data from PricewaterhouseCoopers and the National Venture Capital Association's MoneyTree Report, between the first quarter of 1995 and through the third quarter of 2015, there were 1,160 venture capital deals in Minnesota totaling more than $7.2 billion (see table below).[13] Data from the MoneyTree Report includes:

> investment activity of professional venture capital firms with or without a US office, SBICs, venture arms of corporations, institutions, investment banks and similar entities whose primary activity is financial investing. Where there are other participants such as angels, corporations, and governments in a qualified and verified financing round, the entire amount of the round is included.[14]

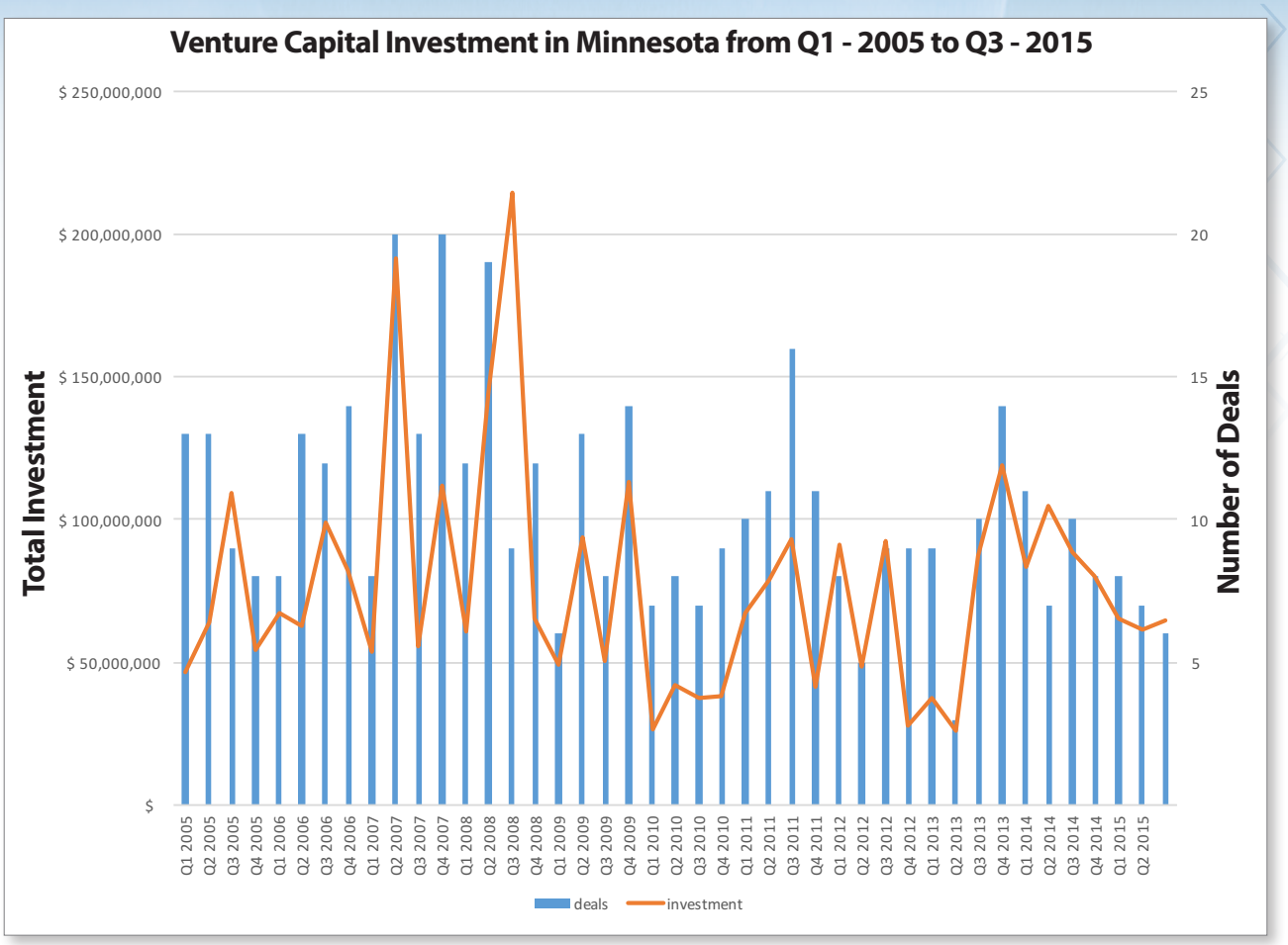
Just more than half of these deals (584 out of 1,160) went to the medical device and equipment and software industries, totaling $3.7 billion (51.8 percent of the total investment). For comparison, between the first quarter of 1995 and through the third quarter of 2015, California yielded nearly 32,000 venture capital deals totaling nearly $311 billion. Over the same time period, Massachusetts yielded more than 8,700 venture capital deals totaling more than $71.5 billion.[15]

Venture Capital Investment in Minnesota by Industry from Q1 1995-Q3 2015

Industry	Total Number of Deals	Total Investment	Last Investment
Medical Devices and Equipment	363	$ 2,714,478,700	Q3 2015
Software	221	$ 1,038,602,000	Q3 2015
Media and Entertainment	80	$ 584,835,300	Q3 2015
Biotechnology	65	$ 483,119,300	Q2 2015
Networking and Equipment	26	$ 355,335,500	Q1 2004
Industrial & Energy	85	$ 348,101,600	Q2 2015
Consumer Products & Services	61	$ 341,558,900	Q4 2012
Business Products & Services	34	$ 250,376,100	Q2 2014
IT Services	35	$ 236,609,100	Q3 2015
Healthcare Services	37	$ 235,390,200	Q1 2015
Telecommunications	36	$ 188,366,100	Q4 2012
Retailing & Distribution	16	$ 180,628,500	Q4 2013
Computers & Peripherals	44	$ 139,782,300	Q3 2014
Electronics & Instrumentation	37	$ 92,368,900	Q2 2012
Financial Services	20	$ 51,491,000	Q3 2013

Within Minnesota's medical device and equipment industry there were 363 deals, totaling nearly $2.7 billion, and 221 deals in the software industry, totaling more than $1 billion. Over the same timeframe, there were 80 deals in the media and entertainment industry, totaling nearly $585 million. Minnesota's biotechnology industry attracted 65 deals, totaling more than $483 million.

More recently, the software industry experienced the greatest venture capital investment during the first three quarters of 2015, with six deals totaling more than $98 million. These figures will likely increase throughout the remainder of the year, as Minnesota-based Code42 announced on October 6 that it raised $85 million in Series B funding.[16] Also during the first three quarter of 2015, $41.1 million of venture capital was invested in medical devices and equipment, and $15.3 million of venture capital was invested in media and entertainment. During the first half of 2015, $3.4 million of venture capital was invested in biotechnology companies and $9.2 million of venture capital was invested in industrial and energy companies.[17]



Since 2005, Minnesota has generated nearly $3.3 billion in venture capital investments. The above chart depicts the annual number of venture capital deals and total investment over this timeframe. Years 2007 and 2008 were most fruitful in terms of number of investments, totaling 113 over both years, and bringing in $898.1 million in venture capital. A sharp decline in the number of venture capital deals occurred between the fourth quarter of 2008 and the first quarter of 2009, following the onset of the financial crisis. Following the financial crisis, there was also a sharp decline in total venture capital investments, from an average quarterly investment of $92.6 from 2005 through 2008, to $67.1 million between 2009 and the third quarter of 2015.

Indeed, since the financial crisis struck in 2009 venture capital has overwhelming flowed to three industries: medical devices and equipment, software, and biotechnology. These three industries account for 83.7 percent of the total $1.8 billion in venture capital over this time period. In fact, 56.4 percent of venture capital investments went to medical devices and equipment, 16.7 percent to software, and 10.6 percent to biotechnology. While the magnitude of venture capital investments declined after the Great Recession, the top industries receiving investments remained largely unchanged. To be sure, medical devices and equipment, software, and biotechnology are significant industries in the space of venture-backed companies.

Top Industries in MN by Venture Capital: Q1-2009 to Q3-2015

	Proportion of Total Investment Within State		
Industry	**Minnesota**	**California**	**Massachusetts**
Medical Devices and Equipment	56.38%	6.47%	8.35%
Software	16.74%	38.61%	19.32%
Biotechnology	10.55%	10.79%	34.50%

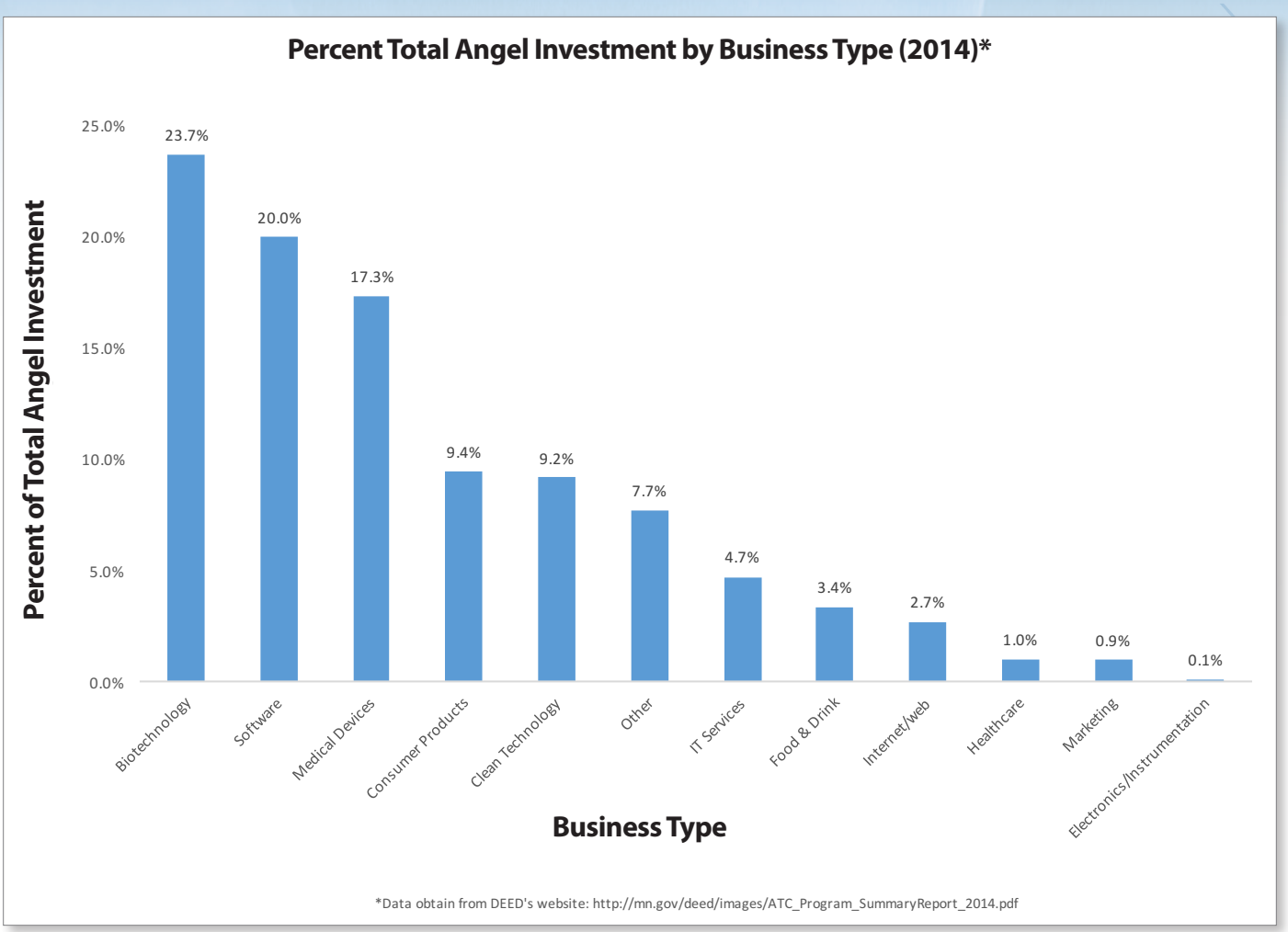
The proportion of venture capital, between the first quarter of 2009 and through the third quarter of 2015, flowing to medical devices and equipment (56 percent) in Minnesota is significantly higher than that in California and Massachusetts, which yield nearly 6.5 percent and 8.3 percent respectively (see table above). While software received that second highest share of venture capital in Minnesota (at 16.7 percent), a greater share of venture capital flowed to software in California (38.6 percent) and Massachusetts (19.3 percent). Minnesota is comparable to California in terms of its proportion of venture capital investment in biotechnology, with 10.6 percent of Minnesota's venture capital and 10.8 percent of California's venture capital flowing to biotechnology. On the other hand, biotechnology captured 34.5 percent of venture capital in Massachusetts.

Overall, the three industries noted in the above table account for 83.7 percent of Minnesota's total venture capital investments. The same three industries account for 55.8 percent of California's venture capital investments, and 62.2 percent of Massachusetts's venture capital investments. Despite California and Massachusetts exceeding Minnesota's absolute investment in medical devices and equipment, software, and biotechnology, these industries reflect a greater share of the venture capital investment in Minnesota, compared to California and Massachusetts.

4.2 Angel Investment

Angel investors play an important role in stimulating investment in Minnesota's high-tech startups. Minnesota's Angel Investor tax credit provides a 25 percent tax credit to qualified investors that make qualified investment in qualified companies; the credit is distributed on a first-come, first-receive basis. Prior to the creation of the tax credit, there was not a convenient way to track angel investment; since its creation, the Department of Employment and Economic Development (DEED) has kept track of this investment activity. Since the Minnesota State Legislature created the Angel Investor tax credit in 2010, more than $246.8 million of angel investment has flowed to Minnesota companies.[18]

In 2010, the first year that the credit was available, 67 businesses received qualified investments; 113 businesses received qualified investments in 2011; 117 businesses received qualified investments in 2012; 128 businesses received qualified investments in 2013; and 110 businesses received qualified investments in 2014. The first year of the tax credit yielded the smallest investment at $28.0 million, growing to $63.1 million in 2011. More recently, in 2014, there was $59.8 million in investment related to the Angel Investor tax credit.



In 2014, the first year that DEED recorded investment by industry, biotechnology companies received 23.7 percent of qualified angel investment, with the software and medical device companies receiving 20.0 percent and 17.3 percent, respectively. Together, these three industries accounted for 61 percent of the total angel investments in 2014.[19] These figures are commensurate with the historical venture capital data noted in the previous sub-section, in which companies related to medical devices, biotechnology, and software take a large share of the total angel and venture funding.

4.3 Summary

Investments from angel investors and venture capitalists play an important role in funding early-stage companies. Investments made by these groups in Minnesota have largely focused on Minnesota's historical strengths in medical devices, and relatedly, biotechnology, as well as software. Attracting less investment from angel investors are the industries of electronics and instrumentation, marketing, healthcare, Internet, food and drink, IT services, clean technology, and consumer products. From a venture capital perspective, the following industries have received a smaller share of investment: healthcare services, telecommunications, industrial/energy, computers and peripherals, electronics/instrumentation, financial services, and IT services.

Highlighting and building on Minnesota's strengths with respect to the medical device, biotechnology, and software industries offers the greatest likelihood of enhancing Minnesota's entrepreneurial ecosystem and overall economic and innovation competitiveness. These industries reflect not only the areas in which new businesses are growing but also reflect Minnesota's historical strengths. Strengthening investments in the areas on which Minnesota already has a strong foundation is key to enhancing Minnesota's economic and innovation competitiveness.

5. University Research

While Minnesota has a number of colleges and universities, those within the Minnesota State Colleges and Universities (MnSCU) system and private colleges and universities have a different focus than the University of Minnesota, the state's only research university. Where the University of Minnesota is focused on research, these institutions are focused on teaching and preparing students for the workforce. Indeed, *US News and World Reports* ranks Carlton College in Northfield, Minnesota as having the best undergraduate teaching among national liberal arts colleges. Macalester College and St. Olaf College also tie for sixth in terms of the best undergraduate teaching among national liberal arts colleges.[20]

Furthermore, 12.3 percent of Carlton College graduates go on to earn a doctoral degree in a STEM field, which ranks sixth overall and third among traditional liberal arts schools. Macalester College is also ranked in the top ten among liberal arts schools with respect to the proportion of graduates who earn a doctoral degree in science or engineering.[21] The MnSCU system also has a number of two- and four-year degree programs—from computer programming to biotechnology/biochemistry to nanotechnology and robotic/instrumentation technology—that prepare students for today's workforce.[22] While preparation for a career in science and technology is indeed and important topic, this will be the focus of future reports.

An important piece of Minnesota's innovation picture is the work done at the state's only research university, the University of Minnesota. Indeed, the University of Minnesota spends $800 million annually on research and development, which is the ninth highest level of R&D spending in the country among universities.[23] Like other leading universities across the country, some of the research conducted at the University of Minnesota is patented and licensed for use by commercial companies, while other research is patented and spun off to form new companies. The university's Office of Technology Commercialization helps with this process, and has had increasing success. Between 2010 and 2014, the Office of Technology Commercialization has filed 545 new patents, has created 48 startups, and has generated $206.5 million in gross revenue.[24]

The quality of the University of Minnesota's research strengths and research initiatives determine, in part, the quality of the talent each attracts. By focusing on the University of Minnesota's research strengths, there are opportunities to build on and enhance various research initiatives within the university as it focuses its research efforts and partners with industry.

5.1 University of Minnesota Graduate Programs

As the University of Minnesota and the State of Minnesota look to attract top talent, both in terms of researchers and professionals, it is instructive to note some of the university's research strengths. The University of Minnesota's graduate programs are ripe for attracting top research talent that might one day develop novel technologies or make scientific breakthroughs that go on to form the basis of a new company. Of particular note are the university's graduate programs in chemical engineering, applied mathematics, and combinatorics/discrete mathematics.

The University of Minnesota's chemical engineering graduate program is ranked fifth by *U.S. News & World Reports*.[25] While the University of Minnesota's mathematics graduate program is ranked 17th overall,[26] the sub-disciplines of applied mathematics and combinatorics/discrete mathematics are ranked fifth and eighth, respectively.[27,28] These disciplines and sub-disciplines represent some of the highest quality graduate programs in the country.

The chemical engineering graduate program is located in the College of Science and Engineering's Department of Chemical Engineering and Material Science. The 14 research areas within the department range from biological engineering to nanomaterials and nanotechnology to electrochemical materials and devices. The department is particularly strong in applied and computational mathematics, and catalysis, separations and reaction engineering.[29] Work within the applied and computational mathematics division focuses on:

> developing and applying ever more powerful tools applied toward mathematical analysis and computational simulation in fields ranging from solid-state materials to chemical reactions to biological systems to fluid dynamics. Ongoing efforts in applied and computational mathematics range from analytical and numerical models to describe physical phenomena, from atomistic to continuum, to systems-level analysis, control, and optimization.[30]

The department's work in the area of catalysis, separations and reaction engineering has focused on "experiments and simulations to identify reaction mechanisms, to the synthesis of new enzymes, microbes, nanoporous catalysts, separation membranes and adsorbents and their use in novel sustainable processes for the production of fuels, pharmaceuticals, specialty and commodity chemicals, and other products."[31]

The Department of Chemical Engineering and Material Science's strength in applied and computational mathematics is perhaps related to the School of Mathematics' strength in applied mathematics, where research topics include continuum mechanics, soft condensed matter physics and materials science, mathematical biology, computational physics, scientific computing/numerical analysis, among other areas. Further, the School of Mathematics is home to the Institute for Mathematics and its Applications (IMA), which brings together scientists, engineers, and mathematicians to address scientific and technological challenges.[32] The school is also home to the Program in Applied, Computational & Industrial Mathematics, which shares research topics in applied mathematics with the Department of Chemical Engineering and Material Science.[33]

The university's strengths in chemical engineering, applied mathematics, and combinatorics/discrete mathematics are potentially fruitful areas for continued collaboration with industry and might present opportunities for the creation of novel technologies, resulting in commercial products. The University of Minnesota, in partnership with the State of Minnesota, also recently formed Minnesota's Discovery, Research, and InnoVation Economy (MnDRIVE), which we explore next.

5.2 MnDRIVE

MnDRIVE is a university-led initiative, funded with $36 million from the State of Minnesota, which "aligns areas of university strength with the state's key and emerging industries to advance new discoveries that address grand challenges".[34] MnDRIVE focuses on four key areas: (1) robotics; (2) global food; (3) environment; and (4) brain conditions. The missions of the various research areas are provided in the table below.

MnDRIVE Research Visions
Robotics
The initiative will provide critical innovations, education, and training in relevant disciplines in engineering, materials science, computer science, and mathematics, and application domains. In addition, partnerships in the areas of the initiative with industries in technology, healthcare, food, and agriculture will be strengthened to the economic benefit of the State of Minnesota and its citizens. Immediate examples of application areas include precision agriculture, environmental monitoring, surgical robotics, and 3D printing.
Global Food
This core MnDRIVE area aims to advance industry practices and public policy to promote global food protection and grow consumers' confidence in the food they buy, develop new markets for sustainable development to address resource constraints on water and energy and train the next generation of food scientists.
Environment
This core MnDRIVE area will perform research with the goal of developing technologies around bioremediation to solve environmental challenges in the state while collaborating with industry leaders to target the most critical environmental challenges. In the long-term, targeted efforts will lead to both improved water quality across the Iron Range and the Mississippi and Minnesota River watersheds, and greater employment and commerce.
Brain Conditions
This core MnDRIVE area will strengthen the university's brain and neuromodulation research infrastructure and capacity and pioneer new technology and applications that decrease the incidence of neurological disease and transform how we prevent, treat and cure diseases. The university will leverage its investments in medicine and engineering and partnerships with the state's medical device industry, ranked second largest in the nation, and national and global efforts.

Two of the MnDRIVE research areas, robotics and brain conditions, seem to be particularly well-suited for the university's research strengths. Neuromodulation, and the development of new technologies to treat brain ailments, is closely related to the research conducted by the Department of Chemical Engineering and Material Sciences, with research areas in electrochemical material and devices, biological engineering, and applied and computational mathematics. Robotics, with its emphasis on a number of disciplines, including mathematics and material sciences, and potential impact on health sciences and surgical robotics, is also well-suited to the university's research strengths. Continuing to strengthen the connection between the MnDRIVE robotics and brain condition research areas and chemical engineering and mathematics offers fruitful opportunities for discovery and innovation.

5.3 Summary

The University of Minnesota's research strengths in applied mathematics, combinatorics/discrete mathematics, and chemical engineering present an opportunity for collaboration between industry and academia. With the formation of MnDRIVE, this is happening already to some degree. By focusing on Minnesota's historical strengths in the medical device industry, in conjunction with current and potential future industry trends, the University of Minnesota, in partnership with industry, are well-positioned to continue to develop novel, innovative technologies.

6. Conclusion

The preceding discussion focused on Minnesota's strengths as they relate to innovation, startups, and university-related research. Identifying common threads across the strengths in each of these areas might help in the formulation of policies and strategies for enhancing Minnesota's economic and innovation competitiveness.

Minnesota's Science and Technology Strengths

Univ. of MN Grad. Programs Ranked in the Top 10	MnDRIVE	Industries by Angel Investment (2014)	Industries by Venture Capital (2009-2015)
Applied Math	Robotics	Biotechnology	Medical Devices & Equip.
Combinatorics	Global food	Software	Software
Chemical Engineering	Environment Brain conditions	Medical Devices	Biotechnology

A key piece of Minnesota's economic competitiveness lies in its historical and current successes with respect to innovations in the medical device industry. Indeed, the medical device, software, and biotechnology industries are key industries for investments from angel investors and venture capitalists alike. Perhaps not surprisingly, these same industries also fuel many of the patents issued to Minnesota entities.

Further, the University of Minnesota's chemical engineering and mathematics graduate programs, with their connections to medical devices, are held in high esteem. While mathematics (even applied mathematics) might operate at the level of abstraction, its motivation can stem from practical problems in industry. Indeed, this is the case at the University of Minnesota.

Connecting (applied) mathematicians with industry, with the University of Minnesota's Department of Chemical Engineering and Materials Science mediating between them, presents an opportunity for some of Minnesota's best researchers and strongest businesses to collaborate in an effort to solve challenging, practical problems in science and technology. While the Institute for Mathematics and its Applications (IMA) does this to some degree, making more explicit the connections between industry and interdisciplinary research teams could spawn greater innovation, especially when coupled with the University of Minnesota's Office of Technology Commercialization.

Additionally, opportunities for collaboration and the creation of novel technologies might exist at the intersection of software, biotechnology, and medical devices. With Minnesota's startup strengths focused on these areas, strengthening the connection between them—and key academic researchers—could lead to breakthrough technologies and discoveries.

Building on Minnesota's commercial strengths in medical device, software, and biotechnology, together with its academic strengths in mathematics and chemical engineering is key to helping enhance Minnesota's innovation competitiveness. Fostering an environment of collaboration between these key industries and academic research areas offers the most fruitful opportunities for technology advancement and innovation.

Endnotes

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About Minnesota High Tech Association

The Minnesota High Tech Association (MHTA) is a non-profit association of more than 300 technology companies and organizations. Together, we fuel Minnesota's prosperity through innovation and technology. Our members include some of the world's leading corporations, mid-sized companies and startups. We are united behind a common vision to make Minnesota one of the country's top five technology states. Minnesota High Tech Association members represent IT, bio-sciences, advanced manufacturing, clean, green and edtech. Once a company or organization joins MHTA, all of its employees become members.

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