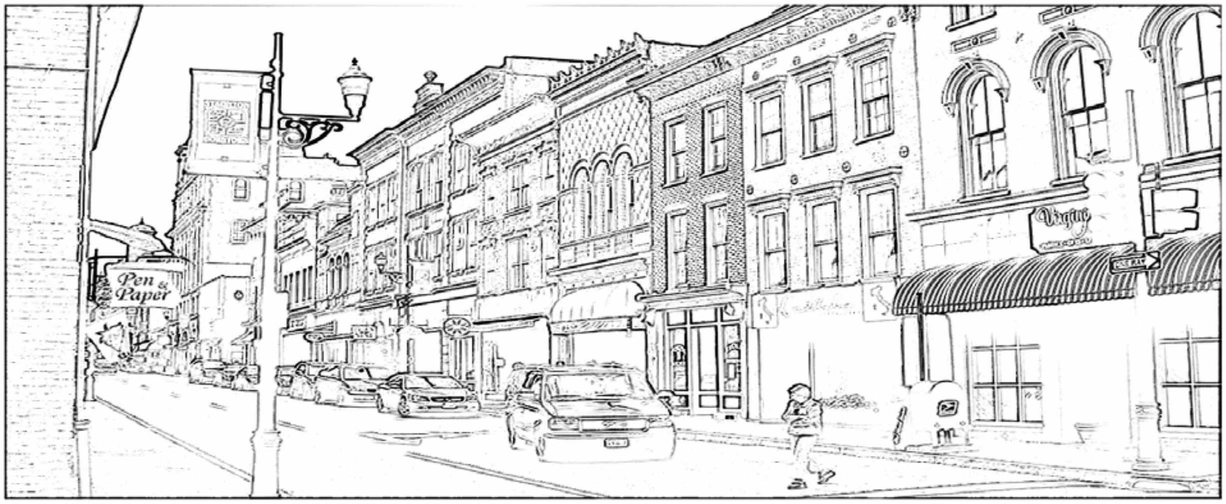

Innovation and Economic Performance: R&D within Wisconsin

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Innovation and Economic Performance:
R&D within Wisconsin

Key Findings

- Innovation, which is linked to human capital, is vital to economic growth and development.
- Wisconsin ranks 20th in the nation for innovation, measured by spending on research and development (R&D), but is lagging behind neighboring states.
- While the majority of spending on R&D in Wisconsin comes from businesses, the University of Wisconsin – Madison accounts for about 27% of all R&D expenditures in Wisconsin. The level of R&D spending by the UW-Madison, however, has been declining over the past several years.
- Compared to the nation, Wisconsin is less active in the most innovative industries. This could limit the potential for sustained economic growth and development.

Innovation and Economic Performance:
R&D within Wisconsin

Introduction

Economists disagree on most issues, but there is widespread agreement that innovation is a driver of economic growth and development. Early economist Joseph Schumpeter described a process of "creative destruction" wherein new innovative ideas, processes and products replace (e.g., destroy) existing technology, and these advancements spur economic growth. Innovation is rarely the result of random events but rather a purposeful outcome of intellectual activity. Innovators identify a new way to accomplish some task or a different way to use a resource. These discoveries are the innovations that drive economic growth and development.

It is true that some innovations are "accidentally" discovered. As a classic example, Alexander Fleming discovered penicillin when a Petri dish containing Staphylococcus was accidently left open. Or Percy Spencer, an American engineer working for Raytheon, walked in front of a magnetron, a vacuum tube used to generate microwaves, and noticed that the chocolate bar in his pocket melted; an observation that led to a now standard kitchen appliance, the microwave. Swiss engineer Georges de Mestral found burrs clinging to his pants and also to his dog's fur. On closer inspection, he found that the burr's hooks would cling to anything loop-shaped. Seeking to restructure that effect in the laboratory he created Velcro. Though "accidental" in a sense, these discoveries were either discovered or refined into marketable products by way of very intentional efforts. By seeking to better understand some event or process, new ideas are created which in turns drives an innovation that adds value or increases productivity, ultimately resulting in economic growth and development.

Innovations are valuable because of the ways they enhance quality, accelerate processes, and satisfy both known and not-yet known human needs and wants. Because of their value, it is straightforward to see why many businesses view research, development, and innovation as part of profitable business plan. These innovative firms, and to a lesser extent early adopters of these innovations, are able to capture the profit windfall from being the first to market with the innovation. Depending on the nature of the innovation, patent protections can even give the innovative firm some monopoly power over pricing and revenue. Thus firms have a strong profit motive to invest in research and development with the end goal of bringing a profitable innovation to market.

Innovation, however, is not the only way to drive profitability. Many firms drive profitability by focusing on reducing costs. For these types of firms, a "positive" business climate is one with low labor and land costs along with limited taxing and regulatory costs. In contrast, innovative firms look at business climate through a very different lens. These firms are looking for communities with two characteristics: (1) diverse pool of highly skilled people (sometimes referred to as a "thick labor market") and (2) other innovative firms (many times thought of as innovation clusters). When these two characteristics are combined, quality of life of the community becomes very important; what types of communities do these highly skilled people and innovative firms tend to seek? Things like cultural events, arts and entertainment venues, diversity in dining opportunities, recreational opportunities, and quality public services such as schools, libraries, parks and public safety come to the forefront.

> Innovative firms view business climate very differently than those businesses that focus on the cost of operations. These two different views of business climate can lead to policy conflicts.

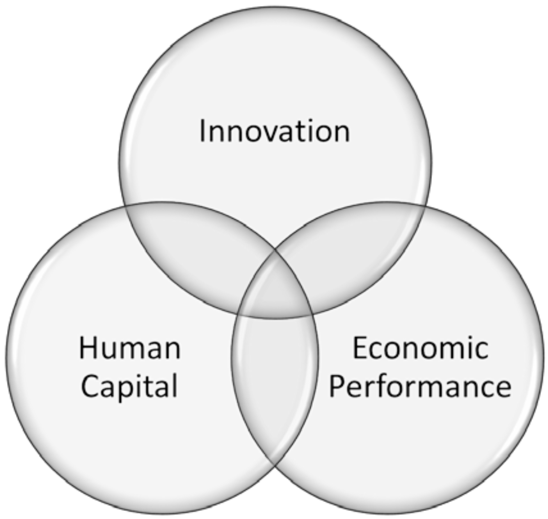
It is true that many firms pursue strategies that promote both innovation and cost efficiencies. At issue within the firm is the balance between investing in research and development of new ideas and products and making those investment decisions in a cost efficient way. A firm that is looking to expand is likely calculating the balance between the costs of local taxes and the benefit of the services those taxes pay for that their employees find attractive such as schools and infrastructure. Much of the current research (e.g., Lynch 2004; Stallmann and Deller 2011) find that taxes do indeed matter but tend to be outweighed by the quality of the services offered.

The question that we address in this study is the relationship between research and development, innovation, human capital or educational levels and economic performance. We first describe the innovation milieu. The descriptive analysis first considers national trends, then focuses in Wisconsin. Particular attention is paid to how Wisconsin compares to the rest of the U.S. and its implication on future economic growth and development.

The Innovation Milieu

Consider the "innovation milieu" as outlined in Figure 1, which captures the interplay of innovation, human capital and economic performance. The interface between innovation and economic performance is well understood in both academic and policy making circles. Firms that are innovators—those bringing new ideas, processes and products to the market—create an advantage over their

Figure 1: Innovation Milieu



competitions and are rewarded by higher profits. Indeed, if the innovation is sufficient, the firm can obtain exclusive use of the innovation through the patenting process, which gives the firm market power to earn especially high profits. Such profitable firms create jobs and pay competitive wages which support stronger economic performance of the community and region.

Innovation and Human Capital

The interface between innovation and human capital is also well understood within the academic literature. Innovations are the result of ideas and ideas come from people. Investments in human capital are integral to generating curious and creative people who have valuable ideas that lead to innovation. Innovative firms will seek out places with "thick labor markets" where talent pools are larger and more diverse. In addition, innovative firms will invest in their workforce by encouraging workers to pursue professional development opportunities such as seminars, workshops, and conferences. Many firms attempt to create a work place environment that facilitates the flow of ideas amongst its employees. Office space design consultants are working on ideas such as shared open office spaces, open conference rooms, and walls covered with whiteboards where employees are encouraged to write down ideas and thoughts. Thus, the term "innovative firm" is something of a misnomer. Firms do not innovate; people innovate. "Innovative firms" are simply those that strategically hire and cultivate innovative people and provide the funds that support research and development.

Innovative firms, which in turn require innovative workers, have been shown to drive economic growth and well-being. Economic growth then reinforces itself by creating even thicker labor markets, larger spaces for entrepreneurial activity and the ability of the public sector to invest in services such as public safety, parks and recreational services, and education. Some economists who study economic growth and development processes refer to this as "agglomeration effects" where dynamic cities are the hub of economic growth. This is not to say that smaller or rural places are not sources of innovation, but rather the critical mass (i.e., agglomeration levels) of activity tends to be located in dynamic cities and accelerate the innovation process.

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To explore the interplay between innovation, human capital and economic performance we collected and analyzed U.S. state level data for the period 1999 to 2012. We measure economic performance with per capita income, innovation is measured with the dollar amount (per capita) spent on research and development (R&D) activity and human capital is measured by the percent of the population age 25 years and over with a Bachelor's Degree or higher. The R&D data are drawn from the National Science Foundation and their annual survey of research and development activity.[1,2]

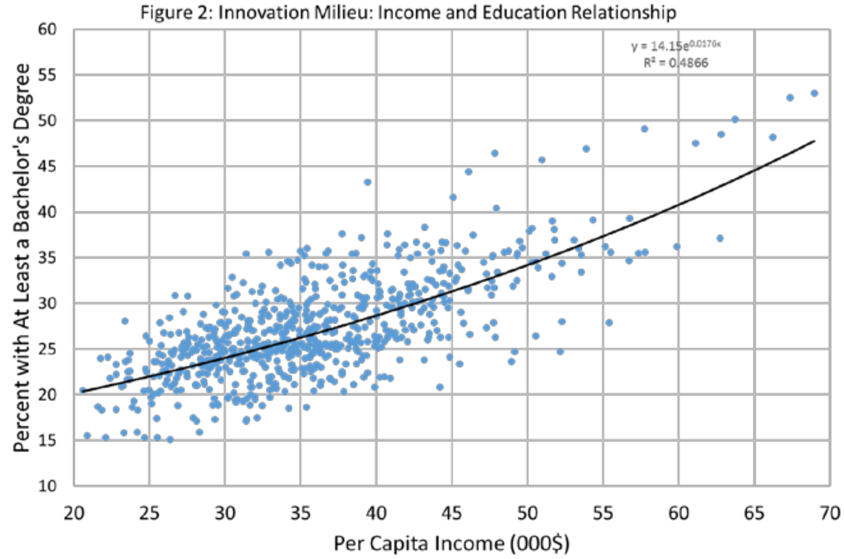
Human Capital and Economic Performance

Consider the simple scatter plot where we look at the relationship between education levels (measured as percent of the population age 25 and older with at least a Bachelor's Degree) and per capita income (Figure 2) by state. There is a strong positive relationship: higher levels of education are linked to higher levels of per capita income. This strong positive relationship is evidence of the link between human capital and economic performance (per capita income) outlined in Figure 1.

Education and Innovation

Next consider the scatter plot were we explore the relationship between spending on research and development (R&D), again by state, on a per capita basis, to educational levels (Figure 3). Again there is a strong positive relationship: states with higher levels of education tend to be states with higher levels of spending on research and development. This positive relationship speaks to the link between human capital and innovation (Figure 1). Firms and institutions (e.g., publically funded research organizations such as universities) tend to draw from thicker labor markets that are characterized by a more educated population. Finally, consider the

Figure 2: Innovation Milieu: Income and Education Relationship



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[1] These data can be found at http://www.nsf.gov/statistics/industry/ and other locations within the NSF website.

[2] Clearly these represent only one potential set of measures to explore. Some researchers suggest that patent data is a better measure of innovation than spending on R&D. But patent data is subject to "pyramiding" where one innovation has multiplier layers of patents. Alternatively, levels of formal education are an important element of thick labor markets but not the sole determinant of innovative human capital. Many innovative entrepreneurs do not have college degrees but larger companies that are best positioned to invest in research and development will only consider hiring people with college degrees.

Figure 3: Innovation Milieu: R&D Spending and Education Relationship

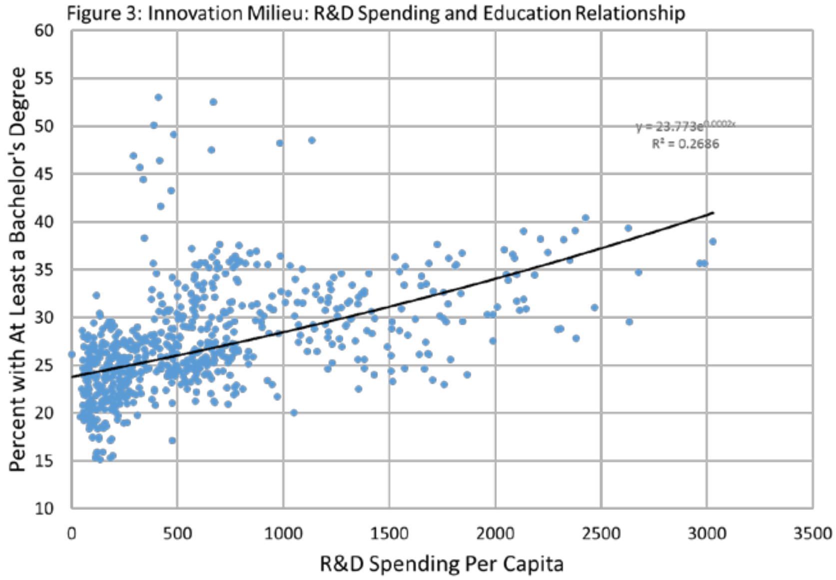
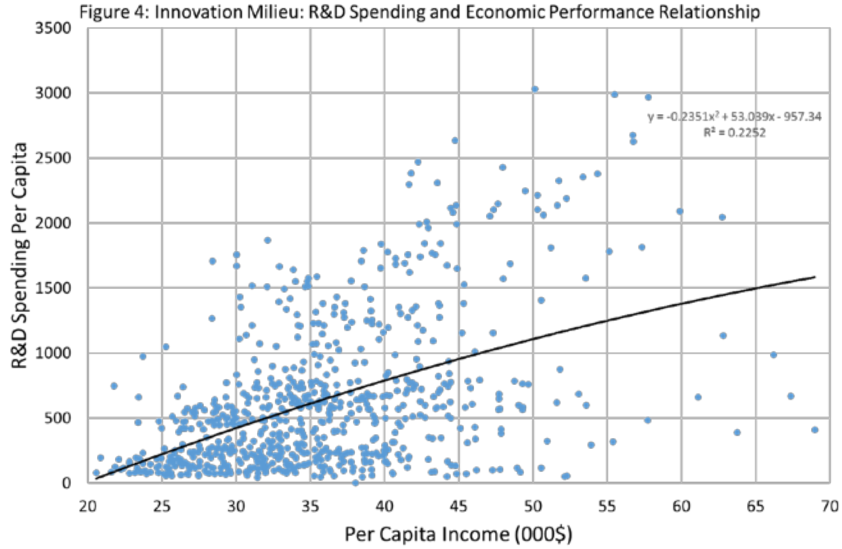


Figure 4: Innovation Milieu: R&D Spending and Economic Performance Relationship



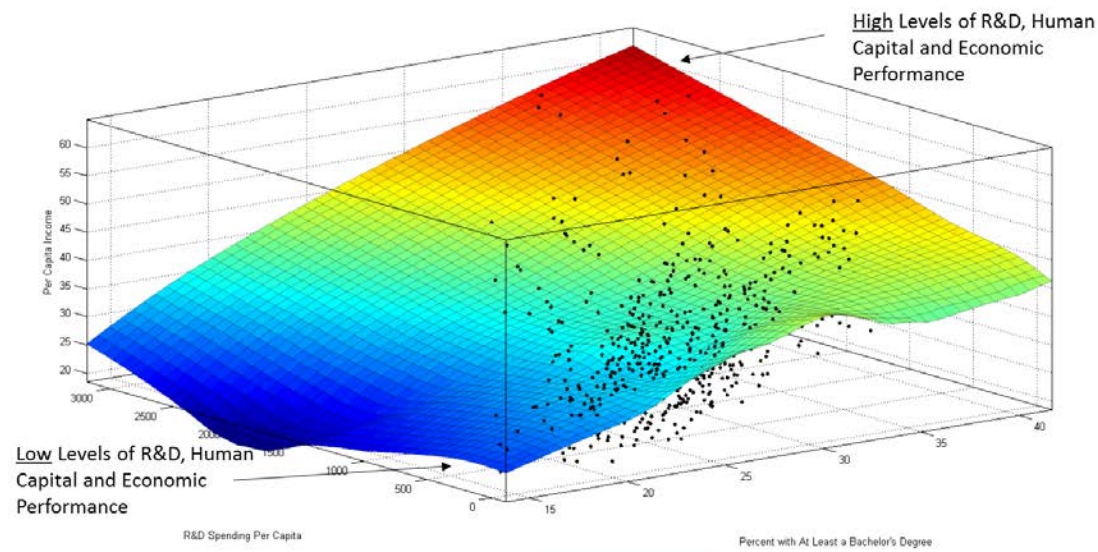
relationship between research and development spending, again on a per capita basis, and economic performance as measured by per capita income (Figure 4). There is again a positive relationship but the relationship is not as strong as those in Figures 2 and 3. This is the third link within the Innovation Milieu outlined in Figure 1 where innovation is linked to economic performance.

Initially, the degree of interplay between the innovation, human capital, and economic performance appears straightforward and easy to comprehend: economic performance is promoted by innovation and people innovate.

Consider the three-dimensional graph combining all three elements (Figure 5). Here rather than a simple trend line, we estimate a relational surface that better reflects the three dimensional nature of the chart. The resulting graph resembles a slope or a hill which is a visual representation of a positive relationship between innovation, human capital and economic performance. The top of the "hill" in red represents states that are highly innovation with lots of human capital; they tend to also have higher income levels. At the bottom of the "hill" in blue are states with low levels innovation and human capital; they also tend to have lower income levels.

While it is clear that the three elements of the Innovation Milieu tend to move together, the "causal" relationships are less clear. Firms and institutions that are more innovative may be drawn to states with higher incomes and educational levels. Or people with higher education could be drawn to states with higher levels of innovation. It is also possible that those with higher levels of education are drawn to

Figure 5: Innovation Milieu: R&D, Human Capital and Economic Performance



states with higher incomes. From a purely policy perspective, understanding which element drives the other would make strategies much more straightforward. Unfortunately, economic thinking around agglomeration economies (or in another sense economic clusters) suggests that each of these elements are intertwined and self-reinforcing. In other words, the presentation of the Innovation Milieu presented in Figure 1 is a vast oversimplification and the overlap of the three core elements is vastly more complex.

A second complicating factor centers on how we define research and development. A standard definition could be, “work directed toward the innovation, introduction, and improvement of products and processes” or “the investigative activities a business conducts to improve existing products and procedures or to lead to the development of new products and procedures”. In the context of maximizing business profit, “research” hinges on the development of new ideas, processes and products and “development” moves those new ideas, processes and products into the market.

Many new things that flow from research turn out to be unsuitable for the market. For example, costs to the consumer may be unreasonable or the improvements over existing products already in the market are not sufficient to justify the costs. For example, in 1943 when computers where just becoming realized, Thomas Watson, president of IBM, infamously stated the “I think there is a world market for maybe five computers.” At the time Mr. Watson might have been correct, computers were bulky, and expensive with limited use. Any firm attempting to bring those early computers to market would have likely failed. But further research and development has brought us powerful computers that can be held in one’s hand.

The nature of research is composed of two parts: basic and applied. Basic research is systematic study directed toward greater knowledge or understanding of the fundamental aspects of phenomena without specific applications towards processes or products in mind. Applied research is a form of systematic inquiry involving the practical application of science. It accesses and uses some part of the research communities' accumulated theories, knowledge, methods, and techniques, for a specific, market driven purpose.

Consider, for example, the progress of stem cells in medical use. The early work on stem cells can be traced back to German researchers in 1860s who were trying to understand how eggs became fertilized. In the 1950s, the work centered on trying to understand why cells mutated into cancerous cells. In the 1980s and 1990s scientists asked if they could develop a "blank cell" or "stem cell" that could be turned into any type of cell (e.g., muscle cell, skin cell, etc.). In 1998, it was University of Wisconsin – Madison scientists James Thomson and Jeffrey Jones that uncovered methods to create human stem cells. All of these questions were being asked out of scientific curiosity. Why do cells turn into different types of cells and can we mimic that process in the laboratory? This is basic research.

> Very few businesses will invest in basic research because of the risk and uncertainty inherent to such research. To encourage basic research the public sector must make those investments.

Now stem cell research has moved into applied research. For example, researchers are exploring whether a blank stem cell can be turned into a heart cell in a consistent and stable manner. Further, work is being done to take information from a heart patient and customize cells to help replace damaged heart cells. These are all applied research questions. If the answer to these questions is yes, then the development stage of the process can take this new technology to market. Is it cost effective? Are there cheaper alternative treatments that have equally positive outcomes? Answers to these questions determine if the process (product) is marketable. There is a clear progression from basic to applied research to development.

When profit is the motivation for investing in the search for new ideas, processes and products and then bringing them to market, businesses are always calculating a cost-benefits analysis with respect to investing limited resources. Clearly, those innovations that have the lowest costs and highest potential benefits (market derived benefits or revenues) will receive the most attention in terms of human capital and financial resources. Those innovations that have high costs and low potential benefits will receive little attention. This calculus that businesses are always undertaking have a significant impact on research, particularly basic research. After incorporating risk factors, the expected return to investments in basic research is usually too low for businesses to justify using limited resources. In the area of basic research, the levels of uncertainty and risk are simply too high for most for-profit firms. Early-stage basic research may have large benefits for both firms and society but is too costly, risky and uncertain for any one person or firm to take on. Left to the market, more specifically profit driven firms, basic research would be under-produced, slowing the process of innovation and economic growth.

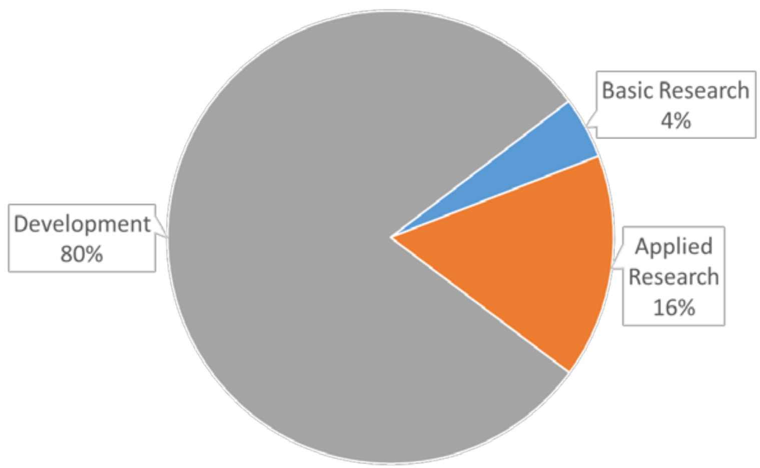
The incentive structure for early-stage or basic research highlights the role of public sector in promoting and supporting such research. Public dollars supporting research universities is but one example. Here university faculty, staff and students can pursue uncertain and risky lines of basic research. Without the pressure to be profitable, university researchers are better positioned to perform basic research than for-profit firms. University faculty, staff and students can work in fields that may have uncertain marketability, identify promising paths, and play a role in guiding subsequent applied research.

The public sector can also encourage for-profit firms to engage in basic research through grants and contracts. The U.S. Department of Defense, for example, supports thousands of for-profit firms that are attempting to develop new technologies. From 2000 to 2015 Wisconsin contractors were awarded $51.6 billion through almost 87,000 contracts. While the vast majority of these awards are *not* related to research and development the potential for Wisconsin firms to receive government support through grants and contracts to help fund R&D, including basic research, can be significant.

If we look at the distribution of R&D spending it is clear that 80 cents of every dollar spent is in the development phase and less than four cents of every dollar is spent on basic research (Figure 6). Clearly businesses prefer to spend limited R&D resources on ideas, processes and products that have the greatest likelihood of making it to market and returning a profit to the business. Often firms take the best ideas that flow from publically funded basic research, such as that conducted at universities, and work toward developing those ideas and the eye toward bringing them to market.

Economists agree, the engine of economic growth and development is innovation, and innovation comes from people with ideas. Businesses are motivated to invest in

Figure 6: U.S. Distribution of R&D Spending: 2013



innovation because it drives profits in a more meaningful and sustainable manner than simply reducing costs. Innovative firms require access to highly educated and skilled workers while at the same time these highly educated and skilled workers are drawn to innovative firms. Layered on top of the notion of agglomeration economies that can be found in more urban areas, we have a formula for economic growth and development. The question facing Wisconsin is how to place itself within this Innovation Milieu.

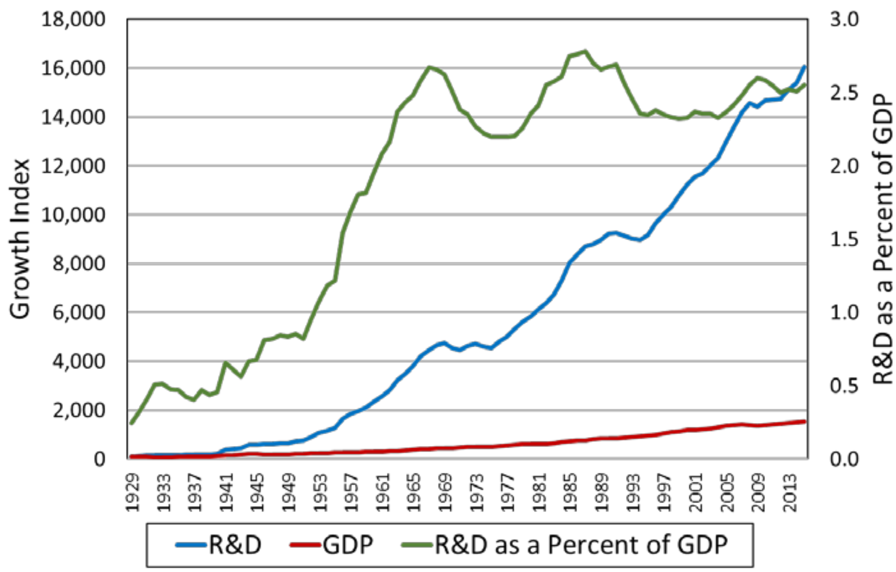
Patterns in R&D Expenditures

One of the difficulties of exploring trends in research and development in the U.S. and Wisconsin is the lack of consistent data.[3] The public entities that are charged with collecting and reporting economic data only recently began to systematically collect data on research and development. Unfortunately, these data are at the national level and are not available for individual states. The bulk of the analysis presented in this report uses the National Science Foundation's R&D expenditure data (see footnote #1). The primary difference is that the accounting of R&D as part of Gross Domestic Product is treated as an investment while the National Science Foundation data treats R&D as an expenditure.

Growth in R&D over Time

Using the newly calculated measures of research and development as part of GDP it becomes clear that R&D grew explosively beginning the early 1950s (Figure 7). Much of this strong growth can be traced to the U.S. government's response to the Cold War and the ensuing "space race" that led to large investments in space exploration led by NASA. Indeed, the U.S. Department of Defense was, and remains so today, a major source of R&D funding. Although the history of Silicon Valley is rich and diverse, much of the initial funding can be traced to U.S. Department of Defense.

Figure 7: Research and Development and GDP (real)



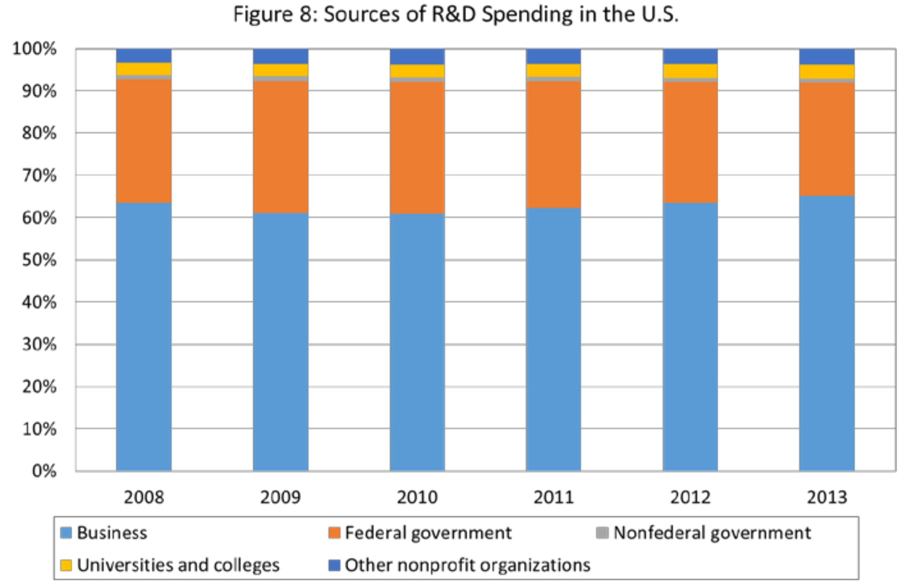
In addition to the growth trend, one can clearly see the effects of recessionary pressures on R&D. During the recessions of the early 1970s and 1990s, R&D spending dropped noticeably. Somewhat surprisingly the Great Recession resulted in only a small

[3] Historically, the U.S. Bureau of Economic Analysis (BEA), the federal agency charged with collecting and reporting Gross Domestic Product (GDP) and related data, did not adequately account for research and development. In 2013, there was a comprehensive change to how research and development was treated relative to GDP. Now BEA treats research and development as an investment in all sectors of the economy. Thus BEA now computes and reports an estimated "value" of research and development. The BEA has recently (2014) recalculated their new interpretation of R&D and applied that recalculation annual back to 1929, the beginning of our current system of measuring the size of the economy (i.e., GDP). It is important to note that the BEA methods are designed to capture the value of R&D and not the current costs of R&D as used in the National Science Foundation's measures of R&D expenditure. For a detailed discussion look here: http://www.bea.gov/faq/index.cfm?faq_id=1028

slowdown in the rate of growth, there was no actual decline. This may suggest that firms have come to realize that innovation drives profitability and recessionary pressures should not distract from both short- and long-term investments in R&D. As a share of GDP, however, R&D has stabilized at around 2.5% for over the past 20 years. One way to interpret this stabilization is that the U.S. economy has reached an equilibrium where growth in R&D more closely matches growth in GDP.

The surge in R&D activity identified in Figure 7 points to the role of the public sector in sparking the growth. Using the National Science Foundation's detailed database on R&D expenditures, it becomes clear that the private sector, particularly businesses opposed to non-profit foundations that are included in the private sector, account for about 65% of spending, followed by the federal government with 27%. The remaining 8% is drawn from nonprofits (4%), universities and colleges (3%) and other governmental entities such as state governments (1%) (Figure 8). Federal sources would include Departments of Defense, Health and Human Services, Agriculture and Energy to name just a few. Much of this money is distributed through institutions such as the National Science Foundation and the National Institute of Health, among others.

Figure 8: Sources of R&D Spending in the U.S.



Sources of Funding

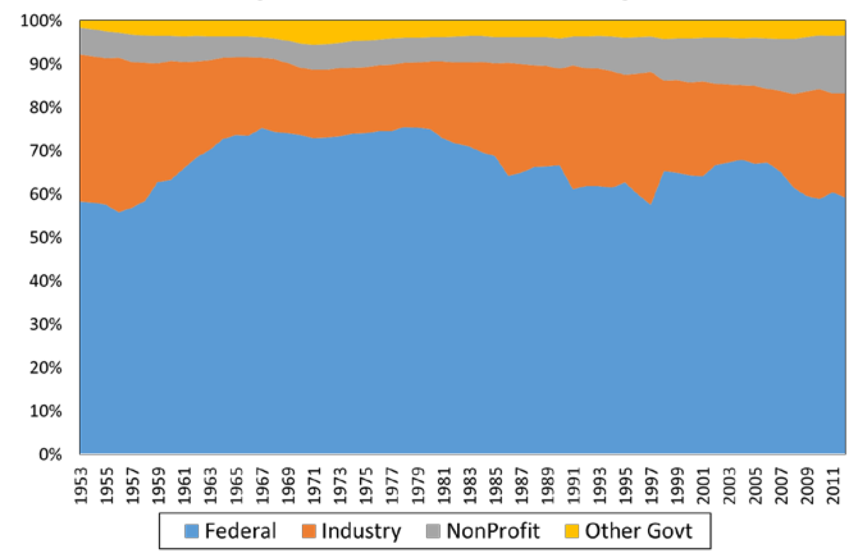
The role of the public sector in funding R&D also becomes clearer when we revisit the different elements of R&D, specifically basic and applied research and development. As described earlier businesses are mostly interested in focusing on innovations that have the highest profit potential within the market. Thus they tend to focus their resources on refining and developing those innovations which result from applied research. The profit potential for innovations that flow from basic research, as defined above, is too risky or uncertain for firms to invest.

But if basic research is the foundation for innovations and businesses tend to be unwilling to invest in that basic research due to uncertainty and risks, who should sponsor or fund basic research? In nearly all countries, including the U.S. funds for basic research come from the public sector either through the federal government or other public entities, such as universities. There are some non-profit research foundations that sponsor basic research, such as the Kavli Foundation, Stuttering Foundation, and the Sarcoma Foundation, but those dollars represent a very small part of the R&D picture. Some universities have established foundations, often in the form of a non-profit, that pool resources from a variety of sources and make those researchers available to university researchers. In Wisconsin, an example would be the Wisconsin Alumni Research Foundation (WARF) which not only pools resources but also helps facilitate the transfer of university sourced innovations into the market place.

Over the past several decades the federal government has been the primary source of funding for basic research (62.3%) followed by the private sector (businesses) (20.6%), then non-profits (6.9%) and other governmental sources such as state governments (3.6%) (Figure 9). While these shares have fluctuated over time, the one sustained pattern is the increased reliance on non-profit organizations whose missions are largely targeted at health care or medical sectors such as the American Diabetes Association or the American Heart Association.

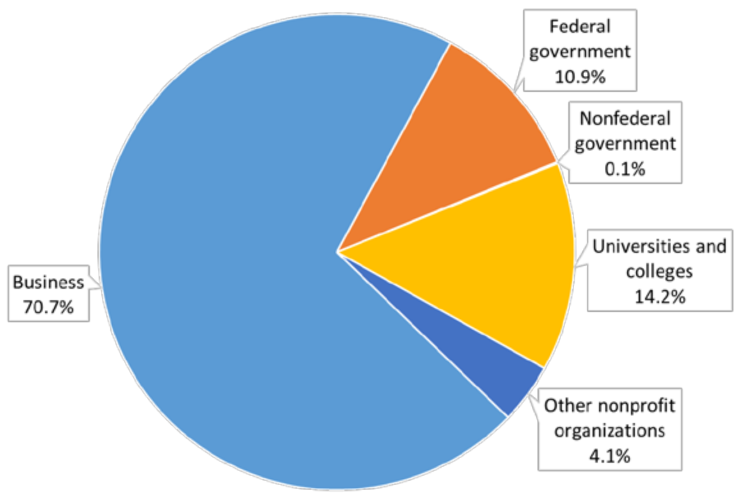
While public sector funding of basic research is a logical policy response, there is constant political pressure to "screen" the nature of basic research. Some lines of research may raise ethical or moral questions in the eyes of some, such as stem cell research, thus becoming a source of conflict. Other times the potential outcomes or marketable innovations that flow from basic research is less than clear; it is inherently uncertain. Consider five separate research centers or laboratories that address a basic research question. It may very well be that in ten years four of the five research programs have not made significant progress but the fifth program uncovered a revolutionary innovation that has significant market potential. The policy question is if the funding for the four efforts that did not yield significant innovations is wasteful. At the same time some policy makers may not appreciate or recognize the potential long-term research outcomes. The challenge is that at the beginning of the ten years we do not know, nor could we set a probability to, the likely success of any of the five efforts. This risk and uncertainty is why for-profit firms will shy away from such work.

Figure 9: Sources of Basic Research Funding



The sources of funding for R&D are different from who conducts the actual research (Figure 10). The federal government accounts for 27% of the money being spent on R&D but performs only 11% of research. Universities and colleges account for only 3% of the sources of R&D money, but accounts for 14% of the actual work, measured by expenditures. In essence, the federal government is providing significant grants and contracts to both universities and colleges as well as businesses to conduct R&D. For example,

Figure 10: Shares of U.S. Total R&D Expenditures, by Performer: 2013



the USDA funds land grant universities to conduct research on agriculture and food and the Department of Defense grants funds to businesses to develop next generation weapon systems. Businesses still conduct most R&D and the bulk of this is at the stage of refining or developing an early-stage innovation; the process of transforming or developing an innovation discovered in basic and applied research into a marketable product or process. For example, in 2011 businesses spent just over $294 billion on R&D, $13 billion (4.4%) was spent on basic research, $47.2 billion (16.1%) on applied research, and $233.9 billion (79.5%) on development.

There is a clear interdependency between innovation, educational attainment and economic performance. Firms invest in research and development with the intent of bringing new innovations to market and earn higher profits. These innovative focused firms rely on highly educated people who tend to be better positioned to conduct the research, develop the innovations into marketable products, and bring those products to market in a profit maximizing manner. There is a balance between the private and public sectors' roles in innovation. Basic research is often a necessary but not a sufficient condition for innovation. Basic research, however, has a high degree of uncertainty as to marketable outcomes. As such, businesses tend to shy away from basic research and focus their resources on applied research and development. If this basic research is to take place, the public sector either in the form of government or non-profit organizations must make the investments. Here universities can and do play a major role both in terms of undertaking the research itself as well as training the workforce that is required in the private sector.

Innovation in Wisconsin

Having looked at the state of innovation nationally in the previous sections we now turn to the specific status of Wisconsin. Our state ranks the top half of states when it comes to innovation as measured by research and development spending. Returning to the National Science Foundation R&D expenditure data we calculated a three-year average from 2010 to 2012 after adjusting for the size (population) of each state. In Wisconsin, businesses, non-profits, combined with universities and colleges spent $707.50 per persons, which ranks Wisconsin 20th in the nation (Table 1). We can see that some of the lowest levels of R&D spending tend to be in poorer more rural states. This is consistent with the concept of the Innovation Milieu (Figures 1 and 5)

Table 1: Rearch and Development Expernditures Per Capita (Average 2010-2012)

	R&D Per Capita	(rank)		R&D Per Capita	(rank)
Alabama	$ 320.21	(32)	Montana	$ 129.05	(45)
Alaska	$ 91.09	(48)	Nebraska	$ 314.91	(33)
Arizona	$ 716.96	(18)	Nevada	$ 242.35	(37)
Arkansas	$ 104.98	(46)	New Hampshire	$ 1,452.01	(7)
California	$ 1,958.34	(5)	New Jersey	$ 1,721.82	(6)
Colorado	$ 801.61	(14)	New Mexico	$ 234.99	(38)
Connecticut	$ 1,982.76	(4)	New York	$ 593.78	(26)
Delaware	$ 2,442.26	(1)	North Carolina	$ 628.20	(22)
Florida	$ 284.85	(35)	North Dakota	$ 349.08	(31)
Georgia	$ 385.66	(30)	Ohio	$ 623.77	(23)
Hawaii	$ 168.75	(41)	Oklahoma	$ 135.99	(44)
Idaho	$ 709.56	(19)	Oregon	$ 1,221.84	(10)
Illinois	$ 965.95	(12)	Pennsylvania	$ 739.88	(17)
Indiana	$ 879.18	(13)	Rhode Island	$ 482.31	(29)
Iowa	$ 655.81	(21)	South Carolina	$ 308.40	(34)
Kansas	$ 588.54	(27)	South Dakota	$ 148.75	(42)
Kentucky	$ 247.28	(36)	Tennessee	$ 214.14	(39)
Louisiana	$ 91.10	(47)	Texas	$ 582.50	(28)
Maine	$ 206.08	(40)	Utah	$ 786.02	(15)
Maryland	$ 771.32	(16)	Vermont	$ 613.81	(25)
Massachusetts	$ 2,380.50	(2)	Virginia	$ 615.43	(24)
Michigan	$ 1,373.79	(8)	Washington	$ 2,081.57	(3)
Minnesota	$ 1,161.96	(11)	West Virginia	$ 142.30	(43)
Mississippi	$ 84.04	(49)	***Wisconsin***	***$ 707.50***	***(20)***
Missouri	$ 1,255.33	(9)	Wyoming	$ 67.38	(50)

discussed earlier in this report. The highest levels of R&D spending are in the lower New England region, particularly Connecticut, Delaware and Massachusetts and the Pacific coast, specifically California and Washington State. Not coincidentally, these states are also home to leading universities such as MIT, and Stanford, and innovative companies such as Amazon, Sony, Microsoft.

If we group states into five equal groups based on their R&D spending per capita, (Figure 11) we find that Wisconsin falls into the middle group, which includes Texas, Ohio, New York as well as North Carolina. But at the same time, our regional competitors, namely Missouri, Minnesota and Michigan are placed into a higher spending group.

Wisconsin in a Regional Context

Consider how Wisconsin has compared to its immediate neighbors (Figure 12). Historically, Wisconsin has ranked 4th of the five states only ahead of Iowa. Michigan has consistently lead the region, but downturns linked to economic recessionary periods are clear. This is likely due to fluctuations in the automobile industry. Overall spending on R&D in Wisconsin has remained stable with modest growth, and compares favorably to many other states, but remains low compared to our immediate neighbors.

Sources of Funding in Wisconsin

When we look at the sources of R&D spending in Wisconsin (Figure 13) it is clear that businesses dominate, accounting for 88.4% in 2012. The federal government accounted for only 1.2% and state government less than one percent. Non-federal/state entities such as the Wisconsin Alumni Research Foundation (WARF), which supports research at the University of

Figure 11: Research and Development Spending Per Capita

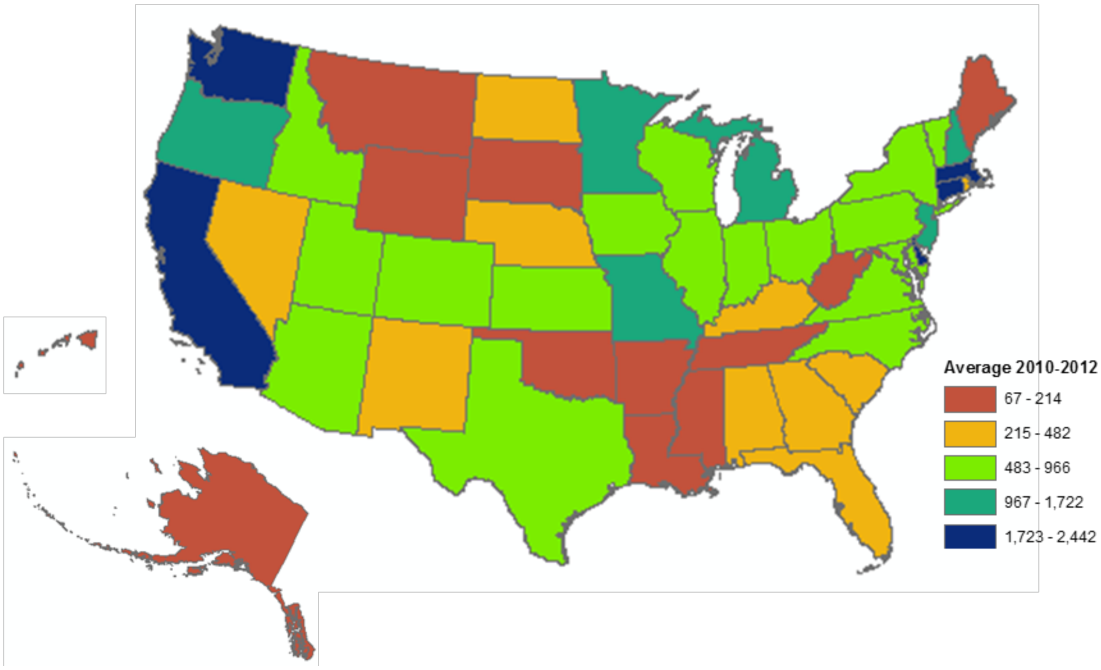
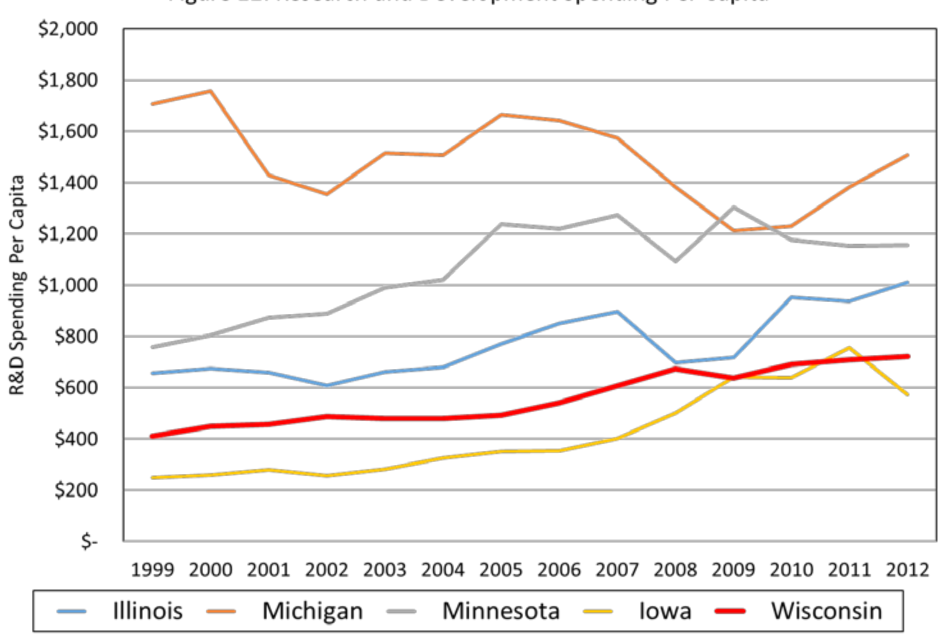


Figure 12: Research and Development Spending Per Capita

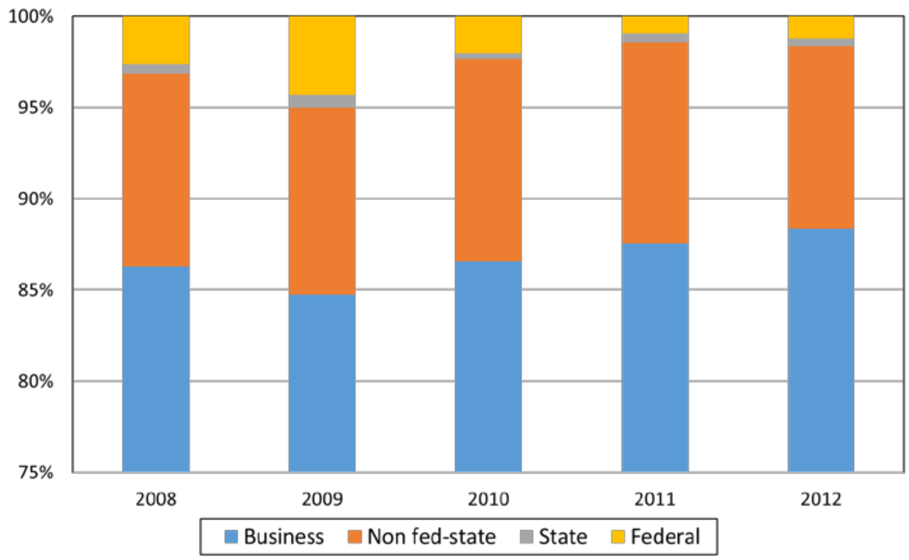


Wisconsin-Madison, accounted for 10.0% of funding for R&D. While these shares have fluctuated somewhat over the past several years, the relative shares have remained mostly consistent.

University Research in Wisconsin

Based on the most recent National Science Foundation data, the University of Wisconsin – Madison ranked 6th in the nation in terms of R&D spending at just under $1.1 billion (Table 2). Indeed, the UW-Madison accounts for more R&D spending than Stanford University or Harvard University. Only the University of Michigan, University of Washington at Seattle, University of California at San

Figure 13: Sources of R&D Spending: Wisconsin



Francisco and University of California at San Diego account for more R&D spending than UW-Madison. John Hopkins University, which also surpasses UW-Madison in R&D spending, is unique because it administers the Applied Physics Laboratory which distributes research funding across the U.S. and internationally.

Looking at the other Big Ten Conference schools, which at one level are the most comparable institutions of higher education, the UW-Madison has the highest level of R&D expenditures. Indeed, R&D spending at the UW-Madison is about twice the level of spending at Purdue University and Michigan State University and more than double the spending levels at the University of Maryland, University of Indiana, University of Iowa and University of Nebraska.

The bulk of the UW-Madison R&D budget comes from the federal government ($548.4 million) through competitive grants/contracts and formula funds (e.g., USDA) and "institutional funds" ($391.4 million). Much of the latter funding comes through the Wisconsin Alumni Research Foundation or WARF. Compared to the other top R&D universities, UW-Madison performs somewhat lower on funding from businesses. This is perhaps a reflection of the dominance of economic activity (employment) in low R&D industries (Figure 15).

Figure 14: Trends in R&D Expenditures at the University of Wisconsin-Madison

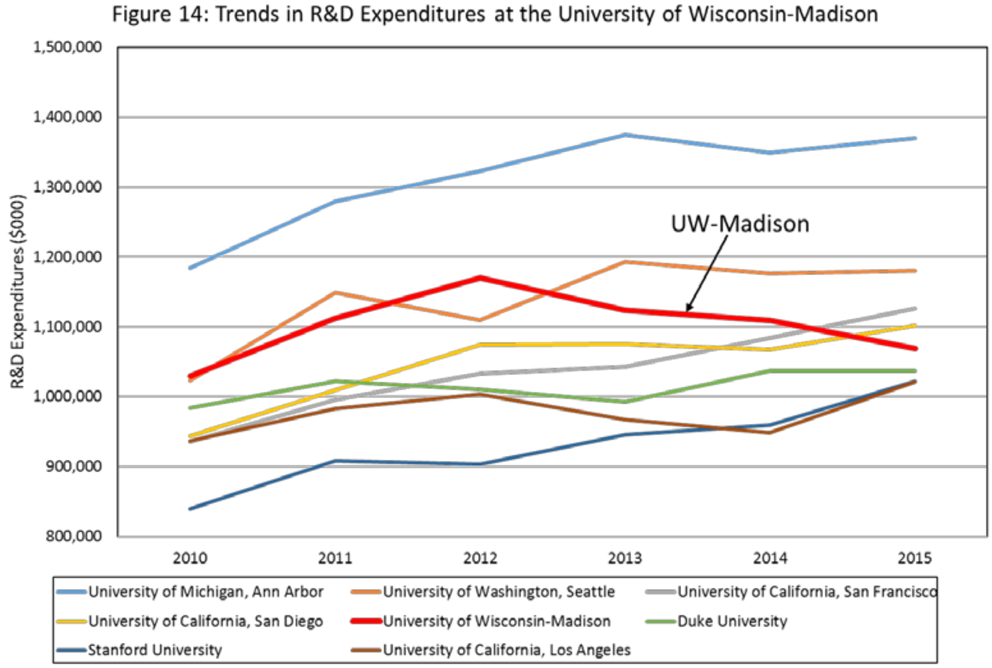


Table 2: Research and Development Expenditures by University (2015)

Institution	Rank	R&D Exp ($000)
Top Ten U.S. Research Universities		
Johns Hopkins University[1]	1	2,305,679
University of Michigan, Ann Arbor	2	1,369,278
University of Washington, Seattle	3	1,180,563
University of California, San Francisco	4	1,126,620
University of California, San Diego	5	1,101,466
University of Wisconsin-Madison	***6***	***1,069,077***
Duke University	7	1,036,698
Stanford University	8	1,022,551
University of California, Los Angeles	9	1,021,227
Harvard University	10	1,013,753
Big Ten Schools		
University of Minnesota, Twin Cities	14	880,618
Ohio State University, The	20	817,881
Pennsylvania State University	22	791,031
Northwestern University	29	656,167
University of Illinois at Urbana-Champaign	32	639,817
Rutgers, The State University of New Jersey	33	628,613
Purdue University, West Lafayette	37	558,611
Michigan State University	38	558,248
University of Maryland, College Park	43	505,699
Indiana University, Bloomington	46	485,076
University of Iowa	49	443,218
University of Nebraska-Lincoln	79	284,438
Wisconsin and UW Campuses		
Medical College of Wisconsin	104	199,283
University of Wisconsin-Milwaukee	171	63,414
University of Wisconsin-Stevens Point	403	4,532
Milwaukee School of Engineering	404	4,524
University of Wisconsin-La Crosse	433	3,615
University of Wisconsin-Oshkosh	503	2,236
University of Wisconsin-Eau Claire	513	2,051
University of Wisconsin-Green Bay	586	1,320
University of Wisconsin-Platteville	641	970
University of Wisconsin-Stout	707	614
University of Wisconsin-Whitewater	707	614
University of Wisconsin-River Falls	776	408
University of Wisconsin-Superior	895	150

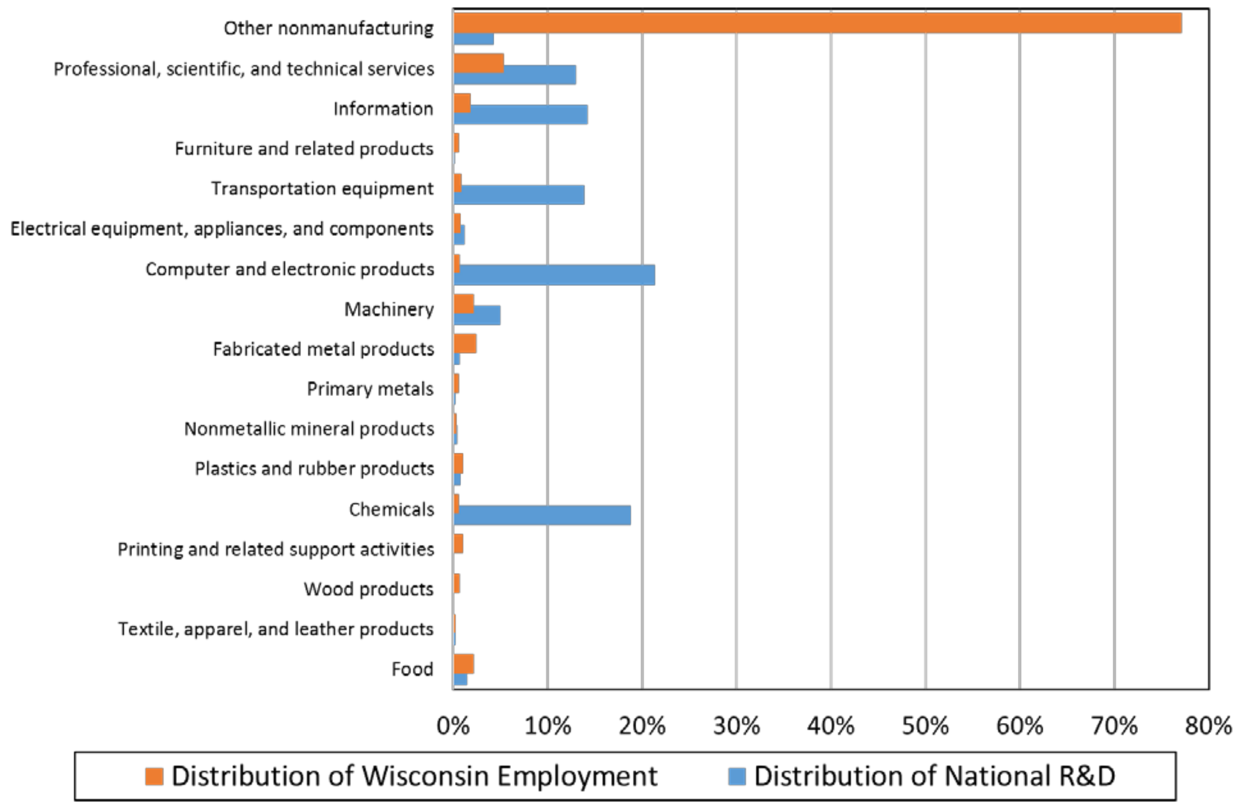
1: Johns Hopkins University includes Applied Physics Laboratory.

As noted in the NSF university R&D data, the UW-Madison is not the only source of basic and applied research, nor is it the only place developing new innovations into marketable products. Both the Medical School of Wisconsin and the UW-Milwaukee are significant sources of R&D activity in Wisconsin. The other UW campuses also play a significant role.

The academic research has suggested that there is a major distinction between universities that are predominately teaching institutions and those with large research missions. There are economies of scale and scope within R&D, or "agglomeration effects", which are difficult to replicate at predominately teaching institutions. From a policy perspective the challenge is striking the right balance between investing in R&D and instructional education (Figure 1). But it is vital to keep in mind that innovations that drive economic growth and development comes from things people do and investment in people through educational opportunities plays an equally important role.

While the University of Wisconsin-Madison is a national powerhouse in research and development investments, the levels of

Figure 15: Distribution of U.S. R&D Spending and Wisconsin Employment



investment have been declining over the past several years (Figure 14). As recently as 2009 the UW-Madison ranked only behind John Hopkins University (which administers the Applied Physics Laboratory thus is somewhat of an anomaly). Indeed, the national 6th place ranking is the first time in 44 years that the UW-Madison has not been in the top five. Since its peak in 2012 at $1.17B, the level of R&D spending at the UW-Madison has been declining. But this decline does not appear to be a national phenomenon as other top ranked R&D university have seen expenditures increasing. Other schools, such as Stanford University, University of California at San Diego and University of California at San Francisco have seen strong growth in R&D expenditures. Thus, the UW-Madison is experiencing a decline in R&D expenditures while other universities are seeing a noticeable increase. If innovation is vital to the economic future of Wisconsin, this downward trend revealed in Figure 14 is troublesome.

Because the private sector, or businesses, account for such a large share of the R&D spending in Wisconsin, it is important to explore the industry mix in Wisconsin their innovative capacity. In 2011 the computer and electronics products industry spent the most on R&D ($62.7 billion) followed closely by the chemicals industry, which includes pharmaceuticals, ($55.3 billion) then information technology industries ($41.9 billion) and transportation equipment ($40.9 billion) (Figure 15).

But if we look at the distribution of economic activity, proxied by employment, across these industries, we find that Wisconsin has a small share of employment in high R&D industries (Figure 15). For example, while computer and electronic products accounts for nearly 21.3% of all business R&D spending, Wisconsin has only 2.1% of its employment in this sector. Similarly, information related industries account for 14.2% of all business R&D spending, but accounts for only 0.6% of employment in Wisconsin. The largest employment sectors in Wisconsin tend to spend relatively little on R&D.

The pattern revealed in Figure 15 is somewhat alarming: if the bulk of R&D spending in Wisconsin comes from businesses, but most businesses (and employment) are in industries that are not particularly innovative as measured by R&D spending this seems to place Wisconsin at a comparative disadvantage. In other words, it appears that Wisconsin is overly dependent on industries that invest little in innovation through R&D spending.

Conclusions

Economists seldom agree, but there is widespread agreement that innovation is an engine of economic growth and development. Further, innovation is produced by people—people with unique and insightful ideas that command market value. Thus, economic growth and development requires investments both in people (human capital) and research and development (R&D). It is clear from even simple analysis (e.g., Figure 5) that these three elements, innovation, human capital, and economic performance, positively reinforce each other in an Innovation Milieu (Figure 1).

In this study, we used data on research and development spending compiled by the National Science Foundation under the assumption that R&D expenditures is a simple proxy for innovation. We find that Wisconsin ranks high nationally but when compared to our immediately neighboring states Wisconsin appears to fall behind. Over the 2010 to 2012 period, Wisconsin businesses and institutions (e.g., nonprofits, universities and colleges, etc.) spent $708 per person on R&D annually. Minnesota, however, spent $1,162, Illinois $966, Michigan $1,374 and Iowa $656 per person annually. More positively, R&D in Wisconsin has been more stable than our neighbor states and is trending upward (Figure 12).

When we look at the industrial mix of Wisconsin and compare that to the industries that tend to dominate R&D activity there is a disconnect. Wisconsin has very little economic activity, measured by employment, in the industries that invest the most in R&D. For example, computer and electronics, chemicals (pharmaceuticals), information and transportation industries account for most of the R&D spending in the U.S., but those industries account for very little employment in Wisconsin. In essence, Wisconsin's economy tends to be dominated by older legacy industries that tend not to invest in innovation through research and development.

When we look at the industrial mix of Wisconsin and compare that to the industries that tend to dominate R&D activity there is a disconnect. Wisconsin has very little economic activity, measured by employment, in the industries that invest the most in R&D.

The University of Wisconsin, particularly the UW-Madison, does offer one bright spot. Again based on National Science Foundation data, the UW-Madison ranks nationally (4th) amongst universities and colleges in terms of R&D spending. In 2014, the UW-Madison accounted for $1.1 billion in R&D expenditures. If one considers that all R&D spending in Wisconsin is just over $4.1 billion, the UW-Madison accounts for about 27% of all R&D expenditures in Wisconsin. Here the UW System and other Wisconsin colleges including the technical schools contributes to the Innovation Milieu directly through investing in R&D and as well as human capital through their teaching mission. The challenge, given increasingly limited resources, is determining the appropriate balance between investment in R&D and resident instruction.

If the Wisconsin economy is to remain vibrant producing economic opportunities and quality jobs more attention must be paid to the innovativeness of Wisconsin businesses and residents. Over reliance on the traditional legacy industries, which tend to invest less in R&D, may place Wisconsin at a comparative disadvantage in the near and long-term future.

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WARF and UW-Madison

The structure of the Wisconsin Alumni Research Foundation (WARF) is somewhat unique to Wisconsin and provides an inventive institutional structure to facilitate R&D in Wisconsin. In 1925, Harry Steenbock had conceived the idea for WARF as a vehicle to license his vitamin D patents and use the royalties to support research at the University of Wisconsin. Dr. Steenbock's idea was that public monies were used to finance his research and hence the outcomes should remain in the public domain to the greatest extent possible. Today WARF works with faculty and staff to gain patents on new discoveries and administer those patents with the idea that the flow of funds should return primarily to the University of Wisconsin. This could be through the direct selling of the patents or more commonly the licensing of those patents. This latter idea around licensing is important because it allows the outcomes of basic and applied research to be brought into the business world for development and introduction to the markets. WARF not only helps facilitate the patenting and licensing process but helps shepherd the outcome of UW R&D into the market place. This is a major means of how UW feeds into the engine of the Wisconsin economy.