Indiana
Business Review

The Professional and Business Services Sector
Employment Changes Across Indiana Metros

Nanotechnology: Breaking Through the Next Big Frontier of Knowledge

KELLEY SCHOOL OF BUSINESS
INDIANA UNIVERSITY
Indiana Business Research Center

Summer 2007
Providing insight and analysis on Indiana's economic and demographic issues since 1926

Summer 2007
Volume 82, No. 2

www.ibrc.indiana.edu

Table of Contents

From the Editors

Think services and think small. As the *Indiana Business Review* continues its eighty-second year of continuous publication, economists from distinctly different parts of the country bring us two distinctly different slices of our economic world. The first provides a richly detailed trend analysis of the professional and business services sectors in Indiana and the Midwest, while the other exposes us to the small new world of nanotechnology.

The term *nano* comes from the Greek meaning dwarf. In modern science, it means one-billionth and specific to nanotechnology (think very, very small) it denotes one-billionth of a meter. Seen by many as the future of technology, nanotech can endow materials with the characteristics of small, fast, and strong. Economist Joe Kennedy tells us the story of this new technology and explains what it will bring to the global economy as nations compete to become leaders in this new frontier.

Economists Uric Dufrene and James Altmann give us a clear and insightful analysis of the professional and business services sector. Spanning sixteen years, we are given a detailed and graphic analysis of Indiana and its metropolitan areas' growth in professional and business services, providing intriguing evidence that focusing on these services can also promote growth in other sectors.

The Professional and Business Services Sector

Employment Changes Across Indiana Metros

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As the number one manufacturing state in the country, Indiana's economy continues to evolve as manufacturing jobs continue to dwindle. In 1990, manufacturing jobs made up 24 percent of the state's workforce. In 2006, that number was down to 19 percent; meanwhile service-providing jobs increased from 71 percent to 76 percent of the state's workforce.

Education and health care remain two of the largest service sectors in Indiana, but another important service sector, professional and business services, has experienced growth surpassing both the United States and Midwestern neighbors.

Harpel (2006) suggests that the professional and business services (PBS) sector supports economic growth, and sector growth has been largely positive.[1] This article tracks the PBS sector for Indiana metro areas and provides comparative information on Indiana and neighboring states.

Structural Changes in the U.S. Economy

Economies of the world practicing free enterprise almost always evolve along very similar paths but at different time periods in history. As an economy makes the transition from one phase to another, a radical restructuring of its labor force is typically observed. This process can be especially painful for workers in sectors that are slow to adapt to changing conditions.

Economies start out as being almost exclusively agricultural in nature. The United States began this evolutionary process during colonial times when over 90 percent of all workers made their living in farming. As late as the Civil War, more than two-thirds of workers were still employed in agriculture. By the 1920s, more than one-fourth of U.S. workers were still in agriculture, but the percentage of agricultural workers has dropped to about 2 percent since then—with a corresponding massive reduction in the number of farms. States that held on to agriculture as their economic mainstay became economically depressed, particularly when compared to states that embraced the transition to manufacturing economies. By 1925, employment in the manufacturing segment of the economy surpassed employment in agriculture. Manufacturing employment peaked at 19.4 million in 1979 but has subsequently continued to decline to 14.2 million workers as of December 2006. New manufacturing jobs in the United States seem unlikely, with typical projections calling for another half-million or more manufacturing job losses in the coming decade. Such losses can be attributed to increasing automation, improved efficiency, foreign competition, and outsourcing.

Meanwhile the service sector of the economy continued to make significant advances. In 1979, there were 64.9 million U.S. service workers; by December 2006, the number had surged to 113.9 million. The ratio of service workers to manufacturing workers increased from 3.35 in 1979 to 8.05 as of December 2006.

Replacing manufacturing jobs with service jobs often translates into painful wage losses; manufacturing jobs pay 23 percent more than service sector jobs on average. Service jobs are typically thought of as including retail salespeople, food service workers, customer service representatives, janitors, hairdressers, and groundskeepers. U.S. Department of Labor statistics for 2005 verify a significant difference in average mean earnings for these service sector jobs when compared to production jobs. Whereas production jobs paid a mean average annual wage of $29,890 in 2005, food preparation and service jobs paid a mean average annual wage of $17,840 and personal service jobs paid a mean average wage of $22,180.

Fortunately, not all service-related jobs produce lower wages. The service industry also encompasses new job opportunities driven by the transition to a knowledge-based economy. This type of economy is often called an information society where an increasing number of employees work in information jobs that are based on services, education, and creative activities. This transformation is the byproduct of technological progress and the increasing importance of computer technology. An information society generates a large number of high paying jobs that involve working with knowledge and a declining

"Replacing manufacturing jobs with service jobs often translates into painful wage losses; manufacturing jobs pay 23 percent more than service sector jobs on average."

number of jobs that demand low cognitive skills.

The professional, scientific, and technical services subsector is one of the fastest growing sectors in advanced economies and reflects the growing importance of specialists and specialized knowledge (applied knowledge) vs. generalists. Ultimately, the investment in knowledge determines the productivity of the employee, more than the tools, machines, and capital available. The good news for technology specialists is that these jobs pay relatively high salaries. The Dice salary survey found that technology professionals had average 2006 salary increases of 5.2 percent to $73,308 in 2006—up from $69,700 in 2005.[2] Strong demand for technology professionals is documented by starting salary increases of 13.1 percent to $42,414 in 2006. Those with one to two years of technology experience saw 13.8 percent increases. The strong performance of the technological sector of the economy suggests that we take a closer look at jobs that are coded by the government as professional and business services.

> *"In fact, one may view the professional, scientific, and technical subsector as another version of manufacturing: manufacturing of ideas and creativity."*

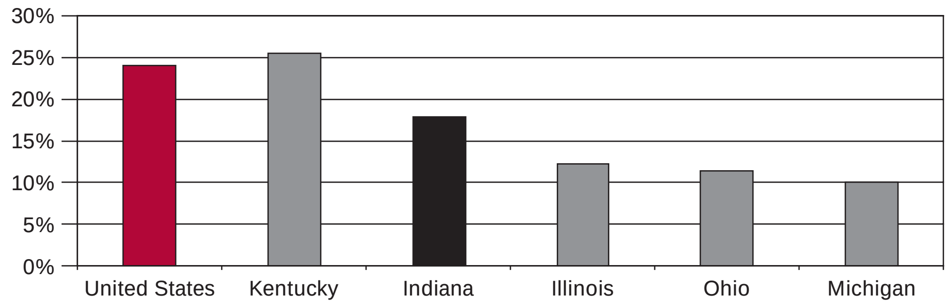
The Professional and Business Services Sector

The professional and business services (PBS) sector includes three subsectors:

- Professional, scientific, and technical
- Management of companies
- Administrative, support and waste management

The first two require a higher skill level and educational attainment. The last, administrative and support services, generally provides routine

Figure 1
Percent Change in Total Nonfarm Payrolls in the Midwest, 1990 to 2006



Source: Bureau of Labor Statistics

services to business, including administrative services, janitorial and building support, travel services, and security. Employment services is the largest component of administrative and support services accounting for almost half of total business services. From an economic development standpoint, administrative and support services serve an important role in overall staffing, especially during tight labor markets.

While all are important components in the PBS sector, the first two provide the technical support to other business sectors that enhances their ability to successfully compete in a global economy. The professional, scientific, and technical services subsector consists of activities such as legal advice, accounting, architectural, engineering, specialized design services, computer services, consulting services, and research services. The management of companies sector consists of firms that hold equity securities in companies for the purpose of controlling and influencing management decisions.

Employment in the professional and business services sector has demonstrated steady growth and reached an all time high in 2006 with 17.5 million employees nationally. PBS sector jobs export services to other geographic regions and often result in a strong multiplier effect for local economies. The PBS sector stimulates innovation, creativity, and entrepreneurial activity and is often credited with being a major factor determining new facility announcements between 1999 and 2005.[3,4]

Indiana's Performance

As the state continues to replace manufacturing jobs with service sector jobs, the PBS sector serves an important role in overall job growth and business attraction. In fact, one may view the professional, scientific, and technical subsector as another version of manufacturing: manufacturing of ideas and creativity. Since manufacturing is still an important component of Indiana's economy, changes for the goods-producing and manufacturing sector are also discussed. With the exception of Kentucky, Indiana has fared better than neighboring states in overall job growth, as well as job growth for the manufacturing and the professional and business services sectors. This article focuses only on percent changes and annual growth rates as opposed to absolute changes.

Total Nonfarm Payrolls

Indiana lagged behind the United States with respect to change in total nonfarm payrolls from 1990 to 2006. The approximate 18 percent change in nonfarm payrolls lags the overall U.S. change of 24 percent (see **Figure 1**). However, Indiana surpassed its neighboring states with the exception of Kentucky.

Four metropolitan areas in Indiana exceeded the U.S. change in job growth. Bloomington, Columbus, Elkhart-Goshen, and Indianapolis all exceeded U.S. job growth over the period 1990 to 2006 (see **Figure 2**). Anderson, Kokomo, and Muncie experienced negative changes in total nonfarm payrolls, with Anderson observing the largest decline.

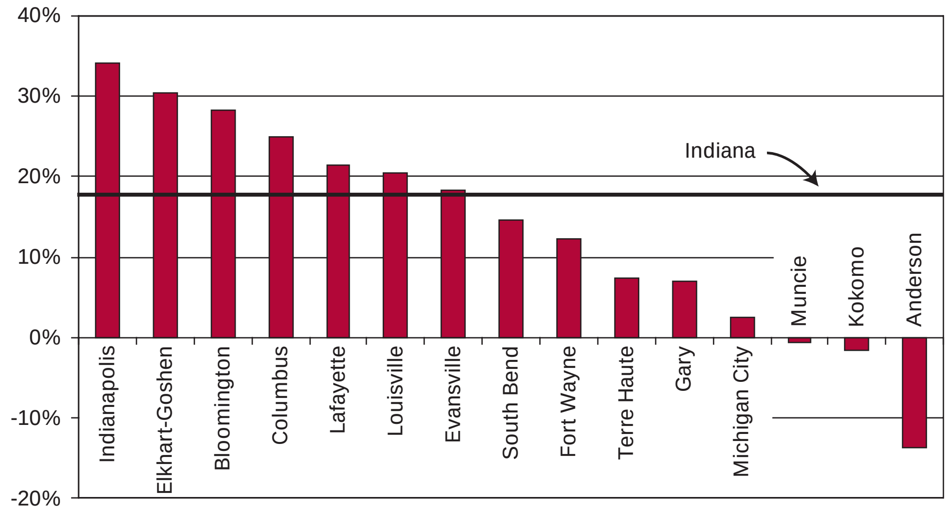
Five-Year Trends: We observe lower annual growth rates over the most recent five-year period. Even though Indiana added jobs, the rate of growth slowed compared to the rate observed from 1990 to 2006 (see **Figure 3**). Despite this slower growth, Indiana added more jobs than its neighboring states, with the exception of Kentucky. Indiana again lagged behind the nation with respect to the annual growth rate.

Across all Indiana metro areas, we also observe average annual growth rates for the most recent five-year period less than the longer term sixteen-year growth rate (see **Figure 4**). One exception was the Elkhart-Goshen metro area. Its five-year annual growth rate of 1.72 percent slightly exceeded the sixteen-year growth rate of 1.68 percent. It should also be noted that Elkhart-Goshen observed healthy gains in both manufacturing and professional and business services over the five-year and sixteen-year period.

Goods-Producing

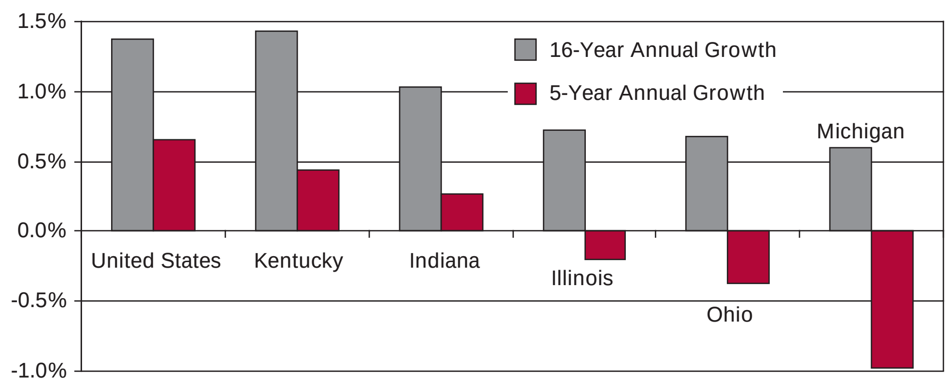
Despite the stereotypical view of declining goods-producing sectors in general, Indiana has not experienced the declines observed in neighboring states, and actually surpassed the nation in overall job growth in goods-producing sectors (see **Figure 5**). Growth in goods-

Figure 2
Percent Change in Total Nonfarm Payrolls in Indiana Metros, 1990 to 2006



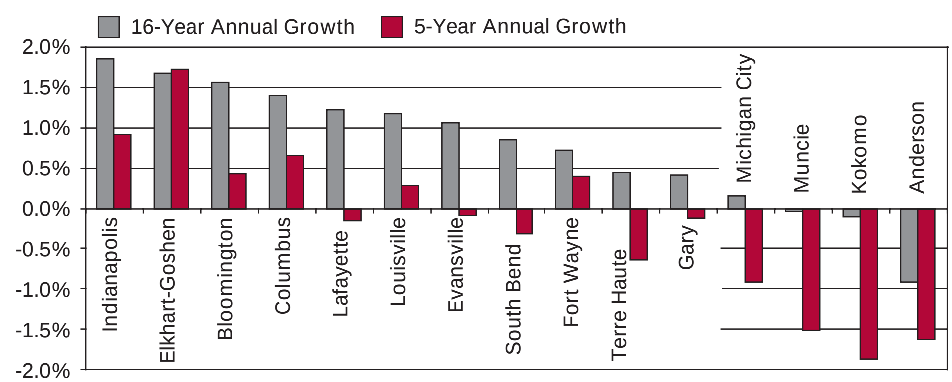
Source: Bureau of Labor Statistics

Figure 3
Annual Growth Rates in Total Nonfarm Payroll



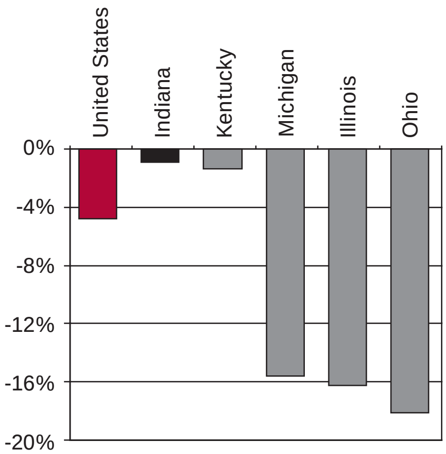
Source: Bureau of Labor Statistics

Figure 4
Annual Growth Rates in Total Nonfarm Payroll



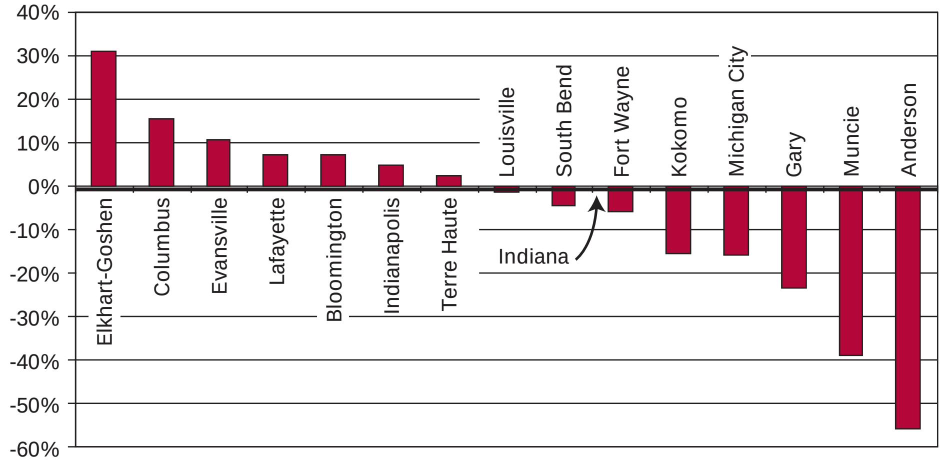
Source: Bureau of Labor Statistics

Figure 5
Percent Change in Goods-Producing Jobs in the Midwest, 1990 to 2006



Source: Bureau of Labor Statistics

Figure 6
Percent Change in Goods-Producing Sectors in Indiana Metros, 1990 to 2006



Source: Bureau of Labor Statistics

producing sectors was nearly flat for Indiana, outperforming its neighbors. Kentucky saw declines of over 1 percent, and Ohio saw the largest decline at 18 percent.

While some Indiana metro areas experienced deep declines in goods-producing sectors, other metro areas experienced significant gains; Bloomington, Columbus, Elkhart-Goshen, Evansville, Indianapolis, Lafayette, and Terre Haute all experienced positive changes (see **Figure 6**). Elkhart-Goshen far exceeded national and state changes with an increase of 31 percent. Metro areas showing significant declines in goods-producing payrolls include Anderson, Muncie, and Gary. Anderson saw the largest decline with a 55 percent negative change in goods-producing payrolls.

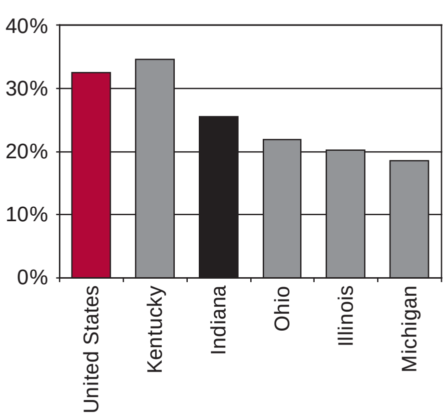
Service-Providing

Indiana's transition to service-providing sector jobs again exceeded all neighboring states with the exception of Kentucky (see **Figure 7**). The addition of service-providing jobs in Indiana did not keep pace with changes in the macro-economy, however. The change in service-providing jobs for the United States stood at 32.5 percent.

Indiana's growth in service-providing industries was positive in all metro areas. Statewide growth in service-providing sectors was approximately 26 percent, with some metro areas significantly exceeding this level of change (see **Figure 8**).

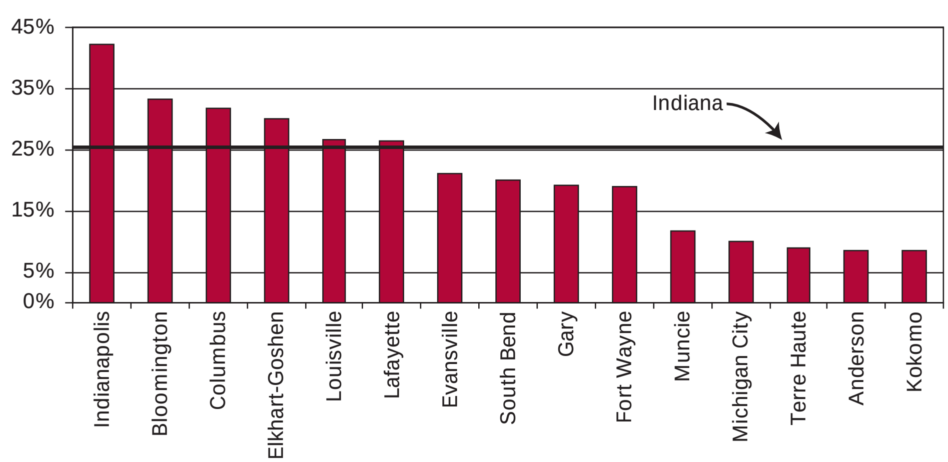
Indianapolis experienced the largest change in service-providing jobs and Bloomington, Columbus, and Elkhart-Goshen also experienced increases that exceeded the state average. Indianapolis and Bloomington were the only two metro areas where the change in service sectors exceeded the national average. Smaller increases were also evident in metro areas that observed smaller changes in nonfarm payrolls. Anderson, Kokomo, Terre Haute, and Muncie all observed changes in service-sector jobs that did not

Figure 7
Percent Change in Service Providing Jobs in the Midwest, 1990 to 2006



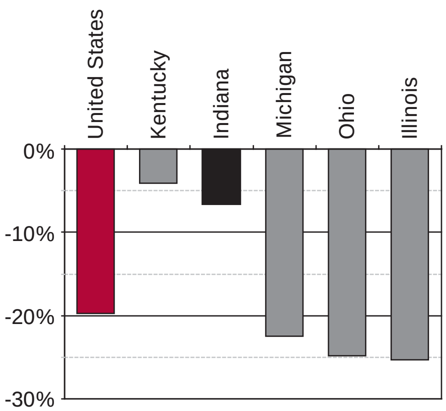
Source: Bureau of Labor Statistics

Figure 8
Percent Change in Service-Providing Jobs in Indiana Metros, 1990 to 2006



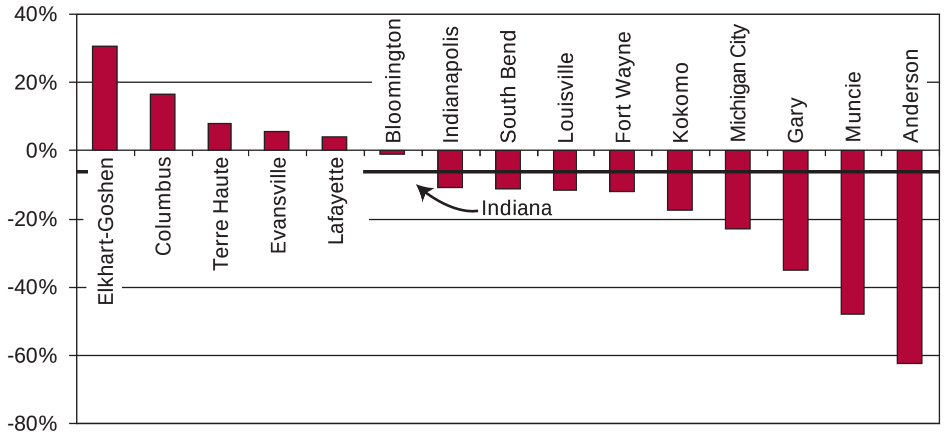
Source: Bureau of Labor Statistics

Figure 9
Percent Change in Manufacturing Jobs in the Midwest, 1990 to 2006



Source: Bureau of Labor Statistics

Figure 10
Percent Change in Manufacturing Jobs in Indiana's Metros, 1990 to 2006



Source: Bureau of Labor Statistics

keep pace with Indiana or the U.S. economy.

Manufacturing

Indiana observed significant swings in manufacturing payrolls across metro areas. Indiana observed a 6.6 percent decline, or a total of 40,000 jobs over the sixteen-year period analyzed (see **Figure 9**). This percentage change in manufacturing employment pales in comparison to the national economy, and was significantly less than the three neighboring states of Illinois, Michigan, and Ohio. Manufacturing job losses for the United States stood at 20 percent and Illinois, Ohio, and Michigan all exceeded 20 percent. Kentucky job losses in manufacturing were 4 percent, slightly less than the 6.6 percent decline for Indiana.

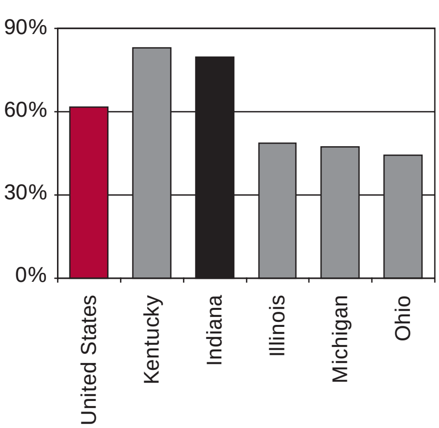
Within Indiana, the largest decrease (62 percent) in manufacturing occurred in Anderson (see **Figure 10**). The largest positive change occurred in the Elkhart-Goshen metro area with an increase exceeding 30 percent. Columbus, Lafayette, Terre Haute, and Evansville also registered positive changes in manufacturing employment. Anderson, Gary, Michigan City, and Muncie all declined more than the nation overall.

It is interesting to note that the largest positive changes in manufacturing employment were experienced by the metro areas that observed the largest changes in service-providing payrolls.

Professional and Business Services Sector

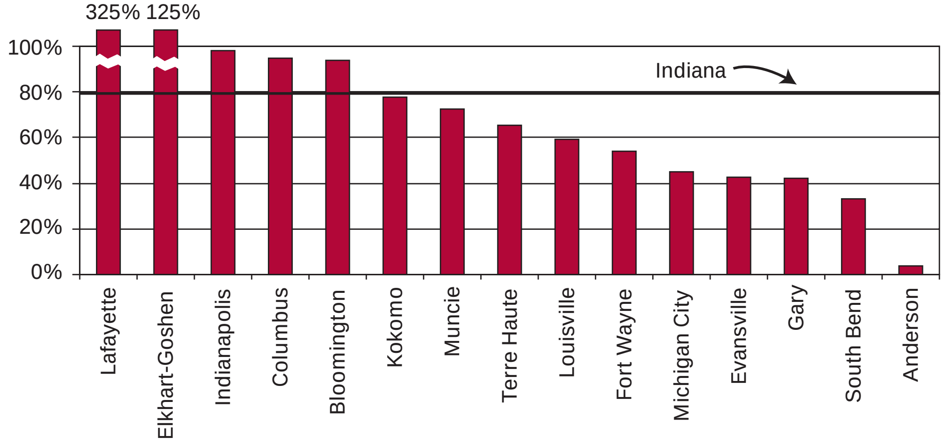
Indiana saw significant percentage gains in the professional and business services sector. Gains in the PBS sector exceeded gains in the United States and surrounding states except for Kentucky (see **Figure 11**). The 80 percent change for Indiana was also almost double the changes observed in Ohio and Illinois. Equally impressive, gains in certain Indiana metro areas far exceeded neighboring states and the nation as a whole (see **Figure 12**).

Figure 11
Percent Change in Professional and Business Services Jobs in the Midwest, 1990 to 2006



Source: Bureau of Labor Statistics

Figure 12
Percent Change in Professional and Business Services Jobs in Indiana Metros, 1990 to 2006



Source: Bureau of Labor Statistics

The Lafayette metro area experienced the largest percentage change in the PBS sector at 325 percent. The smallest increase in PBS sector employees was observed for the Anderson metro region. Anderson also observed the steepest decline in manufacturing jobs. While not all gains in the PBS sector were associated with positive gains in the manufacturing sector, it is interesting to note that the two largest PBS gains, Lafayette and Elkhart-Goshen, were also associated with positive gains in manufacturing. In fact, Elkhart-Goshen had the largest increase in manufacturing at 31 percent and the second largest increase in PBS growth of 125 percent. Bloomington, Columbus, Elkhart, Indianapolis, and Lafayette all experienced changes in PBS employment that exceeded Indiana and U.S. changes.

Average Weekly Wages

Across all Indiana metro areas except for Kokomo, average weekly wages for two out of the three subsectors in the PBS sector exceed the average weekly wage for that region. Wages for the professional, scientific, and technical and management of company's subsectors exceeded the average weekly wages in each respective metro area (see **Table 1**).

In all but one metro area, average weekly wages for the management of companies subsector exceeded average weekly wages for manufacturing. Across all metro areas, the administrative and support services was the lowest paid in terms of average weekly wages. This subsector was less than the average weekly wage in each metro across all industries. Administrative and support services jobs are generally lower skilled positions and require less preparation in terms of education and training, but do provide important support to the overall growth of the PBS sector, as well as other firms.

Conclusion

Indiana has experienced growth in the PBS sector that exceeds both national and neighboring state changes. While the overall PBS sector is small relative to traditional services of education and health care, and the goods-producing manufacturing sector, its overall comparative growth does show promise.

Given that manufacturing continues to decline, the PBS sector is a viable alternative and likewise contributes to economic development at the regional level. Economic developers in Indiana should be familiar with PBS sector growth potential in their region, and might think of explicit strategies to foster and grow this important sector.

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Table 1
Average Weekly Wages in Indiana Metros, 2006

Metro	Weekly Wage	Total	Manufacturing	Professional, Scientific, and Technical Services	Management of Companies and Enterprises	Administrative, Support and Waste Management
Louisville	Average	$595	$728	$712	$914	$431
	Percent	100%	122.4%	119.7%	153.6%	72.4%
Anderson	Average	$611	$989	$657	$1,369	$390
	Percent	100%	161.9%	107.5%	224.1%	63.8%
Bloomington	Average	$584	$766	$706	$2,303	$391
	Percent	100%	131.2%	120.9%	300.7%	67.0%
Columbus	Average	$719	$960	$838	$1,250	$483
	Percent	100%	133.5%	116.6%	173.9%	67.2%
Elkhart-Goshen	Average	$698	$798	$758	$1,570	$410
	Percent	100%	114.3%	108.6%	224.9%	58.7%
Evansville	Average	$692	$1,057	$848	$1,143	$395
	Percent	100%	152.7%	122.5%	165.2%	57.1%
Fort Wayne	Average	$674	$920	$910	$1,027	$440
	Percent	100%	136.5%	135.0%	152.4%	65.3%
Gary	Average	$682	$1,204	$790	$1,209	$477
	Percent	100%	176.5%	115.8%	177.3%	69.9%
Indianapolis	Average	$766	$1,105	$1,056	$1,872	$493
	Percent	100%	144.3%	137.9%	244.4%	64.4%
Kokomo	Average	$874	$1,585	$866	$626	$304
	Percent	100%	181.4%	99.1%	71.6%	34.8%
Lafayette	Average	$662	$899	$753	$1,224	$393
	Percent	100%	135.8%	113.7%	136.2%	59.4%
Michigan City	Average	$596	$770	$623	$906	$403
	Percent	100%	129.2%	104.5%	152.0%	67.6%
Muncie	Average	$580	$880	$734	$932	$283
	Percent	100%	151.7%	126.6%	160.7%	48.8%
South Bend	Average	$677	$916	$858	$1,660	$355
	Percent	100%	135.3%	126.7%	245.2%	52.4%
Terre Haute	Average	$596	$826	$748	$1,088	$401
	Percent	100%	138.6%	125.5%	182.6%	67.3%

Source: STATS Indiana, using ES-202 data

Nanotechnology: Breaking Through the Next Big Frontier of Knowledge

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Nanotechnology is getting big. It is already a driving force in diverse fields such as physics, chemistry, biology, and information sciences. Developments coming out of research labs this year will lead to breakthrough new products in medicine, communications, computing, and material sciences sometime in the next two decades. Its impact on our lives over the next fifty years could rival the combined effects of electricity, the internal combustion engine, and the computer over the last century. As with any new technology, nanotechnology raises some safety concerns. However, its overall effects will be strongly beneficial to all sectors of society.

This article describes what nanotechnology is and how it builds on previous scientific advances. It then discusses the most likely future development of different technologies in a variety of fields and how government policy is aiding scientific advance.

What Is Nanotechnology?

A nanometer (nm) is one billionth of a meter. For comparison purposes, the width of an average hair is 100,000 nanometers. Human blood cells are 2,000 to 5,000 nm long, a strand of DNA has a diameter of 2.5 nm, and a line of ten hydrogen atoms is 1 nm. The last three statistics are especially enlightening. First, even within a blood cell there is a great deal of room at the nanoscale; therefore, nanotechnology holds out the promise of manipulating individual cell structure and function. Second, the ability to understand and manipulate matter at the level of one nanometer is closely related to the ability to understand and manipulate both matter and life at their most basic levels: the atom and the organic molecules that make up DNA.

It is difficult to overestimate nanotechnology's likely implications for society. For one thing, advances in just the last five years have proceeded much faster than even the best experts had predicted. Looking forward, science is likely to continue outrunning expectations, at least in the medium-term. Although science may advance rapidly, technology and daily life are likely to change at a much slower pace for several reasons. First, it takes time for scientific discoveries to become embedded into new products, especially when the market for those products is uncertain.

Second, both individuals and institutions can exhibit a great deal of resistance to change. Because new technology often requires significant organizational change and cost in order to have its full effect, this can delay the social impact of new discoveries. For example, computer technology did not have a noticeable effect on economic productivity until it became widely integrated into business processes. It took firms over a decade to go from replacing the typewriters in their office to rearranging their entire supply chains to take advantage of the Internet. Although some firms adopted new technologies rapidly, others lagged far behind.

Interdisciplinary

Nanotechnology is distinguished by its interdisciplinary nature. The most advanced research and product development increasingly requires knowledge of disciplines that, until now, operated largely independently. These areas include:

Physics: The construction of specific molecules is governed by the physical forces between the individual atoms composing them. Nanotechnology will involve the continued design of novel molecules for specific purposes. In addition, researchers need to understand how quantum physics affects the behavior of matter below a certain scale.

Chemistry: The interaction of different molecules is governed by chemical forces. Nanotechnology will involve the controlled interaction of different molecules. Understanding how different materials interact with each other is a crucial part of designing new nanomaterials to achieve a given purpose.

Biology: A major focus of nanotechnology is the creation of

Nanotechnology is the current stage of a long-term trend toward understanding and manipulating matter at ever smaller scales as time goes by. Over the last century, physicists and biologists have developed a much more detailed understanding of matter at finer and finer levels. At the same time, engineers have gradually acquired the ability to reliably manipulate material to increasingly finer degrees of precision. Although we have long known much of what happens at the nanolevel, the levels of knowledge implied by 1) knowing about the existence of atoms, 2) actually seeing them, 3) manipulating them, and 4) truly understanding how they work, are dramatically different. The last two stages open up significant new technological abilities. At the nanolevel, technology has just recently reached these stages.

small devices capable of processing information and performing tasks on the nanoscale. The process by which information encoded in DNA is used to build proteins, which then go on to perform complex tasks offers one possible template. A better understanding of how biological systems work at the lowest level may allow future scientists to use similar processes to accomplish new purposes. It is also a vital part of all research into medical applications.

Computer Science: Moore's Law and its corollaries, the phenomena whereby the price performance, speed, and capacity of almost every component of the computer and communications industry has improved exponentially over the last several decades, has been accompanied by steady miniaturization. Continued decreases in transistor size face physical barriers including heat dissipation and electron tunneling that require new technologies to get around. In addition, a major issue for the use of any nanodevices will be the need to exchange information with them.

Electrical Engineering: To operate independently, nanodevices will need a steady supply of power. Moving power into and out of devices at that scale represents a unique challenge. Within the field of information technology, control of electric signals is also vital to transistor switches and memory storage. A great deal of research is also going into developing nanotechnologies that can generate and manage power more efficiently.

Mechanical Engineering: Even at the nanolevel, issues such as load bearing, wear, material fatigue, and lubrication still apply. Detailed knowledge of how to actually build devices that do what we want them to do with an acceptable level of confidence will be a critical component of future research.

> *"Detailed knowledge of how to actually build devices that do what we want them to do with an acceptable level of confidence will be a critical component of future research."*

Impacts

With so many sciences having input into nanotechnology research, it is only natural that the results of this research are expected to have a significant impact on four broad applications (nanotechnology, genetics, information technology, and robotics) that interrelate in a number of ways:

Nanotechnology: Nanotechnology often refers to research in a wide number of fields including the three listed below. But in its limited sense, it refers to the ability to observe and manipulate matter at the level of the basic molecules that govern genetics, cell biology, chemical composition, and electronics. Researchers can then apply this ability to advance science in other fields. The broader definition of nanotechnology applies throughout most of this paper, but it is worth remembering that advances in other sciences depend on continued improvements in the ability to observe, understand, and control matter at the nanolevel. This in turn will require more accurate and less expensive instrumentation and better techniques for producing large numbers of nanodevices.

Biotechnology (Genetics): Nanotechnology promises an increased understanding and manipulation of the basic building blocks underlying all living matter. Though the basic theory of genetic inheritance has been known for some time, biologists do not fully understand how life goes from a single fertilized egg to a living animal. Questions exist on exactly how the information encoded in DNA is transcribed, the role of proteins, the internal workings of the cell and many other areas. On a basic level, research is allowing us to tease out the genetic basis for specific diseases and in the future may reliably allow us to correct harmful mutations. But what would a full understanding of the genetic process give us? Could we develop DNA that uses a fifth and sixth molecule? Could the existing process be reprogrammed to code for more than 20 amino acids? To what extent is it possible to create brand new proteins that perform unique functions?

A better understanding of biological processes is obviously needed in order to deliver the health benefits that nanotechnology promises. But it is also important for many reasons outside of biology. Those comfortable with traditional manufacturing techniques may at first have difficulty with the concept of building a product up from the molecular level. Biology offers a template for doing so. A single fertilized egg in the womb eventually becomes a human being: a system of incredible complexity from a simple set of instructions 2.5 nm in diameter. Scientists are hopeful that similar processes can be used to produce a range of other structures.

Information Technology: Progress in information processing has depended on the continued application of Moore's law, which predicts a regular doubling of the number of transistors that can be placed on a computer chip. This has produced exponential improvements in computing speed and price performance. Current computer technology is based on the Complementary Metal Oxide Semiconductor (CMOS). The present generation of computer chips already depends on features as small as 70 nanometers. Foreseeable advances in nanotechnology are likely to extend CMOS technology out to the year 2015. However, at transistor densities beyond that, several problems start to arise. One is the dramatic escalation in the cost of a new fabrication plant to manufacture the chips. These costs must be amortized in the cost of the transistors, keeping them expensive. Second, it becomes increasingly difficult to dissipate the heat caused by the logic devices. Lastly, at such small distances, electrons increasingly tunnel between materials rather than going through the paths programmed for them. As a result of these constraints, any continuation of Moore's Law much beyond 2015 is likely to require the development of one or more new technologies.

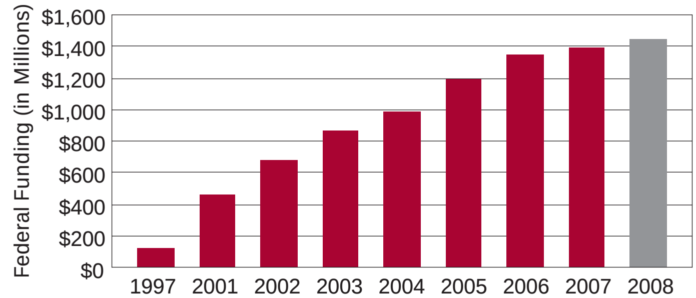
Future advances will likely bring us closer to a world of free memory, ubiquitous data collection, massive serial processing of data using sophisticated software, and lightening-fast, always-on transmission. What happens when almost all information is theoretically available to everyone all the time?

Cognitive Sciences (Robotics): Continued advances in computer science combined with a much better understanding of how the human brain works should allow researchers to develop software capable of duplicating and even improving on many aspects of human intelligence. Although progress in artificial intelligence has lagged the expectations of many of its strongest proponents, specialized software continues to advance at a steady rate. Expert software now outperforms the best humans in a variety of tasks simply because it has instantaneous access to a vast store of information that it can quickly process. In addition, researchers continue to develop a much better understanding of how individual sections of the brain work to perform specific tasks. As processing power continues to get cheaper, more and more of it will be applied to individual problems.

Government Policy Toward Nanotechnology

Nanotechnology is still in its early stages. Many of the most valuable commercial applications are decades away and require continued advances in basic and applied science. As a result, government funding still constitutes a large proportion of total spending on research and development. Within the United States, this spending is guided by the National Nanotechnology Initiative (NNI). The NNI coordinates the policy of twenty-five government agencies, including thirteen that have budgets for nanotechnology research and development. It has set up an infrastructure of over thirty-five institutions across the country to conduct basic research and facilitate the transfer of technology to the private sector. For fiscal year 2008, President Bush has requested $1.45 billion for research directly related to nanotechnology (see **Figure 1**).

Figure 1
U.S. Federal Funding for Nanotechnology Research



Source: U.S. National Nanotechnology Initiative

The NNI's strategic plan sets out four main goals:

- Maintain a world-class research and development program to exploit the full potential of nanotechnology.
- Facilitate the transfer of nanotechnology into products for economic growth, jobs, and other public benefits.
- Develop educational resources, a skilled workforce, and the supporting infrastructure to advance nanotechnology.
- Support responsible development of nanotechnology.

The NNI is clearly geared toward developing the technology on a broad front, correctly seeing it as the source of tremendous benefits to society. Its mission is not to see whether we should go forward with research and development. It is to go forth boldly, while trying to discover and deal with possible risks.

Presently, the United States leads the world in most areas of research. However, other countries, including China, also see research in nanotechnology as being vital to their ability to create value in tomorrow's economy. It is not necessary, nor would it even be desirable, for the United States to lead in every aspect of this broad field. However, continued leadership on a broad range of applications is critical to our nation's continued ability to compete in world markets. In addition, in a few areas, such as defense applications, international leadership has important strategic implications.

What Does Nanotechnology Mean for Us?

The simple answer is that, over the next fifty years, consumers will see a growing range of new products that dramatically transform their lives. If properly managed, these products will dramatically improve human health, change the structure of society, and open up new possibilities for human potential.

On a more basic level, managers must begin to study how today's discoveries could transform their business in the next five to ten years. By now every business, even those far removed from the computer industry, has been significantly affected by the revolution in communications and computing. Nanotechnology's influence will be equally broad. First, it will create the capacity for new products with much better performance characteristics and less waste. Second, by continuing the communications revolution, it will give companies new ways to organize work and distribution lines. Third, it will transform the environment within which the business competes.

The world we live in will continue to get faster, more complex, and smaller.

Indiana
Business Review
Summer 2007

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- **The Professional and Business Services Sector: Employment Changes Across Indiana Metros**
- **Nanotechnology: Breaking Through the Next Big Frontier of Knowledge**

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