Bio-Statistics: Comparing the Productivity and Importance of the Life Sciences

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For decades, the life sciences—centered on the pharmaceutical and medical device industries—have been a powerhouse of innovation, technological advancement and economic growth. This article reports how Indiana's life sciences sector compares to other states.

While there are multiple indicators of industry performance, for example, the number of patents awarded or the employment in the sector, we explore which states have the greatest level of manufacturing productivity and in which states are the life science industries particularly vital to employment and economic growth.

Manufacturing combines the inputs of capital, labor, materials, energy and purchased services to make physical products. Productivity is a measure relating a quantity (or value) of output to the inputs required to produce it. Productivity is often related to the quantity of labor—measured by labor hours or number of workers—required for a given output. But productivity also can describe the quantity of all inputs for a given output. Economists are interested in changes in productivity over time because, as an industry or national economy's productivity grows, so do the returns to labor and capital. Rather than comparing productivity over time, this analysis takes a snapshot of productivity in the life science industries and compares industry productivity across states.

Our research, built through a partnership with BioCrossroads that focuses on life science metrics for Indiana, attempts to answer the question "In which states are the life science industries the most productive?"

Productivity is presented in two ways: 1) the traditional labor productivity that measures labor inputs against output, and 2) the quantity of what is left over—the residual earnings after payroll and materials and other purchased inputs—as a recovery of and return to capital. The latter might be thought of as a profitability measure. The measures used in this analysis do not comport with strict categories of productivity as understood by economic theory, but they do serve well to make comparisons across states.

We then shift attention to evaluating the effect that the life sciences have on state gross domestic product (GDP) and rank the states in terms of life science employment concentration.

Summary of Findings

- *Indiana's manufacturing productivity in pharmaceuticals ranks second in the nation, and productivity in medical devices ranks third.*
- *Indiana ranks third in the nation in labor productivity and third in profitability for the aggregate manufacturing life science category.*
- *Indiana ranks fifth in the country for employment concentration for the entire life science sector, including employment in life science services like research and development in biotechnology and medical labs.*
- *Indiana has the greatest employment concentration in surgical appliance and supplies manufacturing in the country and is second in pharmaceutical preparation manufacturing.*
- *The life science manufacturing industries are an economic output and income booster for Indiana.*

Definitions

A key concept in the theory of the firm in economics is productivity. Productivity measures the degree to which the firm's inputs—labor, energy, capital, resources, raw materials and technology—are combined to produce a volume of output. The firm's goal is to maximize output with a minimum of inputs. Thus, high productivity describes producing more with less (that is, relative to other producers).

Economic output is usually defined as value-added and is comprised mostly of compensation, profits and, in cases for which intellectual property is important, royalties, i.e., returns to patents plus rents, net interest and other miscellaneous income. GDP is the sum of all value-added across the economy. In effect, GDP is income to somebody. Greater productivity, therefore, means greater income.

Ideally, input and output data would be available annually at the most detailed industry level, that is, the six-digit North American Industry Classification System (NAICS). The focus of this part of the analysis is manufacturing and is constrained by the available data. The most current manufacturing data come from the Census Bureau's Annual Survey of Manufacturers (ASM). The greatest level of detail for these annual data are at the four-digit NAICS level. (The complete list of life science industries and the relevant six-digit components are provided in the appendix available at www.ibrc.indiana.edu/ibr/2013/fall/appendix.html.)

As a result, this analysis includes three life science subsectors (identified by four-digit NAICS code), i.e., the subsectors for which life science industries as identified by six-digit NAICS code make up more than 50 percent of annual shipments (based on the detailed 2007 Census of Manufactures). The subsectors are pesticide, fertilizer and other agricultural chemical manufacturing (3253); pharmaceutical and medicine manufacturing (3254); and medical equipment and supplies manufacturing (3391). These three form a "pure-play" definition of the life sciences given the available data.

One should note that a more comprehensive analysis would include sectors other than just manufacturing, for example, R&D in biotechnology, but data for the service sectors are not as comprehensive, detailed or current as manufacturing.

Methodology

We constructed state-level indexes of productivity in life sciences manufacturing using the data categories collected by the ASM. The ASM (and Economic Census) provide a variable called "value-added," which reflects the difference between the final value of an industry's total shipments and the cost of most inputs to produce those shipments. Value-added in this sense is not exactly the same as value-added in national income accounting.[1] While the "materials" variable of the ASM includes raw inputs, energy and contract work performed by others, it leaves out purchased services and overhead. For the purposes of this analysis, the ASM value-added is a reasonable measure for the returns to labor (payroll and benefits), returns to intellectual property and royalties (e.g., on patents), and returns to capital (or profits).

Productivity statistics across states were compared by creating an index using three measures that are used in traditional productivity analysis: value-added per production worker, value-added per production labor hour and value-added per employee (i.e., both production and non-production workers).

Profitability statistics across states were compared by creating an index of three measures: the value-added to shipment ratio, value-added to payroll and materials ratio and value-added to capital expenditures. The latter measure is probably the weakest of the six since capital expenditures on plant and equipment can vary each year and do not include the eminently important capitalized research and development or the purchase of intellectual property, in addition to land or maintenance and repair expenses that extend the life of the plant and equipment. That said, because it treats all firms and industries alike, it does provide a metric to compare investment and returns. Ideally, payroll would include benefits, but the factor to ratchet-up payroll to be fully loaded compensation—that is, wages/salaries plus other compensation including benefits and fringes—is not reported by industry at the state level.

The six measures—three for labor productivity and three for profitability—were compiled for each industry, as well as a combined pure-play life science sector, in each state. Each measure was converted to an index by dividing the state-level productivity metric into the same productivity metric for the nation as a whole. Thus, a value of 1 indicates that the state is exactly as productive or profitable as the U.S. average. Values above 1 indicate greater productivity, and values below 1 indicate lower productivity.

The final state-level indexes consist of a simple average of the three components. For the pure-play life science combination, each index is an industry blend; value-added for pharmaceuticals, devices and agricultural chemicals were added together and worker hours were added together, etc. Thus, in the calculation of the indexes, the pure-play life science sector measures were weighted by the relative size of that industry within the pure-play subsector. Like the individual industry indexes, they are comprised of the simple average of the three component indexes.

Finally, the indexes are reported based on whether there was a complete complement of data or not. Why are there cases without complete data? The Census Bureau will suppress data when the values are not considered statistically robust enough for publishing—recall that this is a survey and a survey can suffer from non-response or under-coverage—or when the data may reveal information particular to individual firms. Comparing states with incomplete or missing data would bias the results, so this article only includes states with complete data. Results for states that were not complete are reported in the appendix.

Findings

For the pharmaceutical industry, there were sufficient data for 25 states. The index values for the top 10 are shown in **Table 1**. All 25 pharmaceutical "complete" states as well as those "suppressed" states can be found in the appendix. Indiana beat out all other states in pharmaceutical manufacturing productivity except for Delaware and was fourth in terms of profitability in 2011.

For the medical equipment industry, there were sufficient data for 29 states. The index values for the top 10 are shown in **Table 2**. All medical equipment states can be found in the appendix. As the table shows, Indiana was fourth, beating out North Carolina in terms of productivity and profitability, but fell below Colorado and Nebraska. That

■ **Table 1: Pharmaceutical and Medicine Manufacturing, 2011**

State	Productivity Index	Profitability Index	Profitability Rank	Average Production Wage	Average Pay	Shipments (in thousands)
Delaware	3.34	1.86	2	$74,626	$88,248	N/A
Indiana	2.80	1.54	4	$66,057	$80,876	18,752,744
North Carolina	2.33	1.74	3	$64,729	$70,996	30,901,774
Tennessee	1.53	1.25	9	$60,834	$91,985	3,308,174
Virginia	1.33	1.89	1	$71,562	$85,295	3,402,322
California	1.14	1.14	10	$62,468	$95,546	36,642,384
Illinois	1.01	0.83	19	$76,257	$110,554	12,848,054
Nebraska	0.91	1.28	6	$55,976	$65,397	1,488,653
New York	0.88	1.05	12	$42,637	$60,941	16,205,130
Texas	0.87	1.50	5	$50,780	$59,225	4,770,121

Source: IBRC, using Annual Survey of Manufacturing data

■ **Table 2: Medical Equipment and Supplies Manufacturing, 2011**

State	Productivity Index	Profitability Index	Profitability Rank	Average Production Wage	Average Pay	Shipments (in thousands)
Colorado	1.72	1.37	6	$36,230	$65,410	2,760,509
Nebraska	1.62	1.27	10	$38,713	$42,447	2,097,152
Indiana	1.59	1.40	5	$40,666	$54,380	7,365,963
North Carolina	1.51	1.35	7	$40,049	$53,098	2,807,768
Arizona	1.47	1.48	3	$41,261	$66,704	1,695,970
Minnesota	1.39	1.07	14	$39,521	$72,560	4,150,320
California	1.31	1.11	13	$39,167	$68,495	17,234,799
Utah	1.30	0.86	24	$46,792	$63,598	1,921,562
Rhode Island	1.26	1.64	2	$32,813	$69,202	620,672
Tennessee	1.18	1.12	12	$30,254	$56,100	2,584,271

Source: IBRC, using Annual Survey of Manufacturing data

■ **Table 3: Pesticide, Fertilizer and Other Agricultural Chemical Manufacturing, 2011**

State	Productivity Index	Profitability Index	Profitability Rank	Average Production Wage	Average Pay	Shipments (in thousands)
Missouri	1.6	1.4	2	$54,365	$65,865	3,395,907
Louisiana	1.5	0.7	9	$82,305	$86,601	4,846,293
Florida	1.1	1.1	6	$58,324	$63,420	6,311,117
Ohio	1.0	1.3	4	$54,434	$60,214	1,484,138
Alabama	0.9	1.3	3	$51,044	$60,749	763,638
Iowa	0.8	1.1	7	$67,148	$56,347	996,699
Georgia	0.7	0.9	8	$37,920	$44,852	1,067,560
North Carolina	0.7	1.5	1	$63,333	$67,081	1,512,049
California	0.6	1.3	5	$44,978	$53,883	1,170,382
Texas	0.5	0.7	10	$63,137	$68,750	1,270,842

Source: IBRC, using Annual Survey of Manufacturing data

View the appendix for this article at www.ibrc.indiana.edu/ibr/2013/fall/appendix.html.

said, Indiana shipped more product than both of those states combined.

The ASM does not report data for Indiana in the pesticide, fertilizer and other agricultural chemical manufacturing industry (NAICS 3253), but it is considered in the set of life science industries. A relative handful of the states (10) have an appreciable presence for this sector. In the case of Louisiana, this industry is the sole entry in the life sciences, whereas in North Carolina or California, the industry plays a relatively minor but still significant role in the life science industry portfolio. **Table 3** presents the productivity of this industry.

Examining the pure-play life sciences category that blends all three industries, Indiana holds its own, ranking third for both productivity and profitability (see **Table 4**). North Carolina, with solid rankings for all three industries and for both productivity and profitability, tops the list. Louisiana rockets up to second place, but recall that their only industry in the mix is agricultural chemicals and that the state's rank for profitability is 35th, likely because they have such a high capital requirement for plant and equipment. Recall that the "blending" of the pure-play life sciences weights each of the component industries and component measures, such as value-added, payroll, shipments or employment, based on the size of the individual component measures.

Indiana is far-and-away the most productive and profitable state in the Midwest in terms of life science manufacturing, with some Midwestern states consistently falling below the national productivity average (see **Figure 1**). The evidence shows clear signs that Indiana is both a major player in the life science sector and a productive player as well. While this represents a 2011 snapshot, Indiana has been in the top position in the Midwest since the last economic census in 2007. The relative ranking and productivity positions have changed little over time, based on the ASM data that run from 2008 to 2011.

Implications for State GDP

Productivity and profitability should also be reflected in economic growth and the standard of living. In an earlier analysis, one looked at the effect that the life science sector has on state per capita personal income.* In this analysis, the attention is turned to the effects on GDP. State-level data on per capita GDP were compared to life science manufacturing productivity by state. While the life sciences are a relatively small portion of state employment, the industries have an outsized effect on state economic output.

Life science productivity has a positive correlation with per capita GDP. Based on the modeled relationship between the productivity of manufacturing medical devices and pharmaceuticals and GDP, every 0.1 increase in the productivity index boosts GDP per capita by $340. In other words, the GDP per capita difference between the most productive state and the least productive state in life science manufacturing in 2011 is $7,760, based on this (admittedly simple) model.

This substantial difference reflects the effect of productivity in just one economic sector on a state's entire economy. The life science industries are certainly an output and income booster for the state. The model would expect a per capita GDP of $46,060 for Indiana—above the national average. But Indiana's actual per capita GDP in 2011 was $36,970—below the national average—even with the GDP boosting effects of the life sciences.

If it weren't for the life sciences, therefore, Indiana's personal income and standard of living would be noticeably worse than it is today. This fact is also reflected in the relative concentration of employment in the life science sector.

* Timothy F. Slaper, "Life Science Industries Increase Indiana's Personal Income," *InContext,* May-June 2013, www.incontext.indiana.edu/2013/may-jun/article1.asp.

The Relative Importance of the Life Sciences

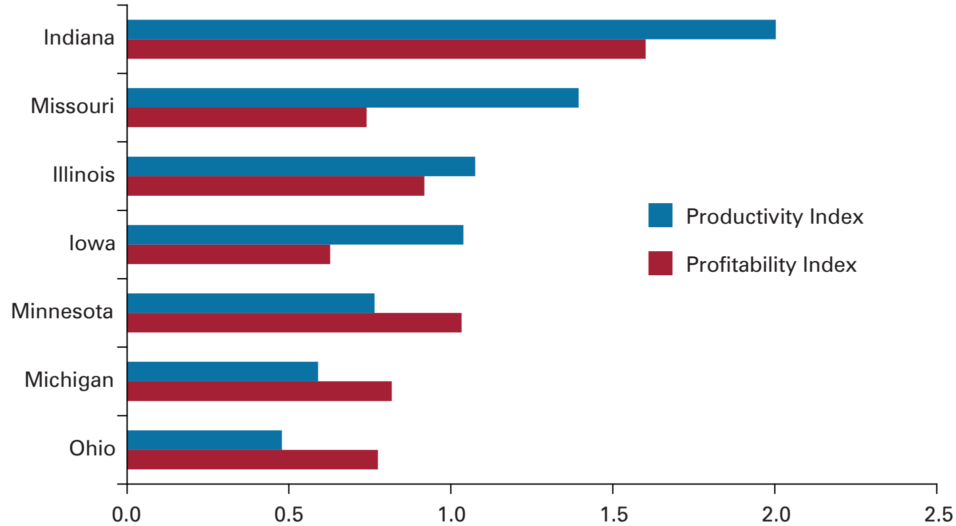
Comparing employment concentration, also known as employment location quotient, using standard government-issued data can be frustrating since much of the information is suppressed. Fortunately, the Indiana Business Research Center has developed algorithms to estimate the "holes" in the data from the Quarterly Census of Employment

Table 4: Top 10 States for the Pure-Play Life Sciences, 2011

State	Productivity Index	Profitability Index	Profitability Rank
North Carolina	2.75	1.82	2
Louisiana	2.16	0.45	35
Indiana	2.00	1.60	3
Nebraska	1.50	1.46	5
Florida	1.47	0.63	32
Missouri	1.39	0.74	30
Maryland	1.37	1.22	9
Virginia	1.33	1.96	1
California	1.19	1.19	11
Tennessee	1.08	1.23	8

Source: IBRC, using Annual Survey of Manufacturing data

■ **Figure 1: Life Science Productivity and Profitability in the Midwest, 2011**



Source: IBRC, using Annual Survey of Manufacturing data

■ **Table 5: Dominant Industries within the Life Sciences—Percentage of National Employment Greater than 3 Percent, 2011**

NAICS	Industry	Percent
325412	Pharmaceutical Preparation Manufacturing	12.5%
334510	Electromedical Apparatus Manufacturing	3.7%
339112	Surgical and Medical Instrument Manufacturing	7.2%
339113	Surgical Appliance and Supplies Manufacturing	6.1%
541711	Research & Design in Biotechnology	8.7%
541712	Research & Design in the Physical, Engineering, and Life Sciences (Except Biotech)*	27.8%
621511	Medical Laboratories	10.2%
621512	Diagnostic Imaging Centers	4.2%

*Employment in 541712 is dominated by the physical sciences and engineering.
Source: IBRC, using Quarterly Census of Employment and Wages data and IBRC estimates for QCEW suppressed data

and Wages (QCEW) at the six-digit level. Using these proprietary data, one can compare the relative importance of various life science industries in the states.

Twenty-four six-digit industries are considered life sciences—by and large derived from the industry set developed by the Battelle Memorial Institute—excluding the other provisional industries in health information technology and specialized transportation and logistics associated with many life science products. To keep the analysis manageable and focused on the industries within life sciences with greater levels of employment, the set of industries was trimmed based on the national percentage of the six-digit industries within the total life science sector. In other words, only high-volume six-digit industries in the U.S. were examined to determine the life science location quotients among the states. These eight industries, presented in **Table 5**, represent 80 percent of the life science sector in the country as a whole.

Table 6 shows the life science industry employment concentration with respect to a state's entire workforce for Midwestern states. It points to where the states are particularly concentrated within the sector. Indiana is particularly heavy in pharmaceutical manufacturing, unlike most of the Midwest. Both the percentage in all life sciences for Indiana and Minnesota (the top line) of 1.7 percent and 1.5 percent, respectively, and the industry concentration rankings (based on location quotients) for these two states for many industries show that they lead the region and hold their own nationwide. It also shows that Minnesota is particularly concentrated in electromedical manufacturing. On the other hand, the entire region, with the exception of Missouri, is not particularly strong in the biotechnology R&D industry.

Indiana's (and the rest of the Midwest's) employment concentration in the service industry of research and design in the physical, engineering and life sciences (except biotech)[2]—"all-purpose R&D"—is, at first look, underwhelming. One may be led to believe that there is a lack of commitment to invention, patents and high-tech in the state. But the industry employment figures may mislead.

There are several reasons to be cautious about interpreting the low concentration in all-purpose R&D as an indicator that the state lacks in technological development in the life sciences, or, for that matter, any high-tech industry. First of all, a majority of the work in the all-purpose R&D industry is not in the life sciences. Second, many, if not most, of the scientists and engineers are counted within their respective manufacturing industry. Based on NAICS industry definitions, the scientists and scientific activity should appear in the all-purpose R&D industry. The data collection and reporting system, however, aggregates them with production workers in the manufacturing establishments. Third, those who track patent filings for the life sciences in Indiana are quick to point out that most patents are awarded to corporations that have headquarters, R&D labs and manufacturing activities all together in one location. This final point became evident as one attempted to understand how the data reports low

■ Table 6: Industry Share of State's Total Workforce in the Life Science Industries and U.S. Ranking in Terms of Employment Concentration, 2011

Leading Life Science Industries	Illinois	Indiana	Kentucky	Michigan	Minnesota	Missouri	Ohio	Wisconsin
Employment in All Life Sciences (Excluding Research & Design in the Physical, Engineering and Life Sciences)	0.89%	1.70%	0.40%	0.73%	1.47%	0.78%	0.68%	0.85%
Rank in the U.S.	18	5	43	26	6	22	31	20
Pharmaceutical Preparation Manufacturing	0.30%	0.52%	0.03%	0.17%	0.05%	0.10%	0.10%	0.07%
Rank in the U.S.	6	2	40	13	29	16	18	23
Electromedical Apparatus Manufacturing	0.02%	0.00%	0.00%	0.01%	0.51%	0.00%	0.01%	0.06%
Rank in the U.S.	22	40	42	30	1	43	27	10
Surgical and Medical Instrument Manufacturing	0.10%	0.33%	0.01%	0.06%	0.36%	0.06%	0.04%	0.07%
Rank in the U.S.	13	4	39	21	2	22	25	17
Surgical Appliance and Supplies Manufacturing	0.05%	0.33%	0.05%	0.16%	0.14%	0.03%	0.10%	0.05%
Rank in the U.S.	30	1	27	5	9	36	13	31
Research & Design in Biotechnology	0.04%	0.05%	0.02%	0.07%	0.04%	0.15%	0.06%	0.03%
Rank in the U.S.	32	24	39	17	29	9	21	33
Research & Design in the Physical, Engineering and Life Sciences (Except Biotech)	0.36%	0.12%	0.05%	0.40%	0.23%	0.24%	0.24%	0.16%
Rank in the U.S.	15	38	50	12	25	24	23	29
Medical Laboratories	0.10%	0.17%	0.10%	0.06%	0.08%	0.12%	0.11%	0.09%
Rank in the U.S.	34	8	32	42	40	23	29	35
Diagnostic Imaging Centers	0.03%	0.03%	0.03%	0.04%	0.02%	0.03%	0.05%	0.02%
Rank in the U.S.	42	38	37	25	46	36	19	47

Note: Shaded cells indicate a top 10 ranking.
Source: IBRC, using Quarterly Census of Employment and Wages data and IBRC estimates for QCEW suppressed data

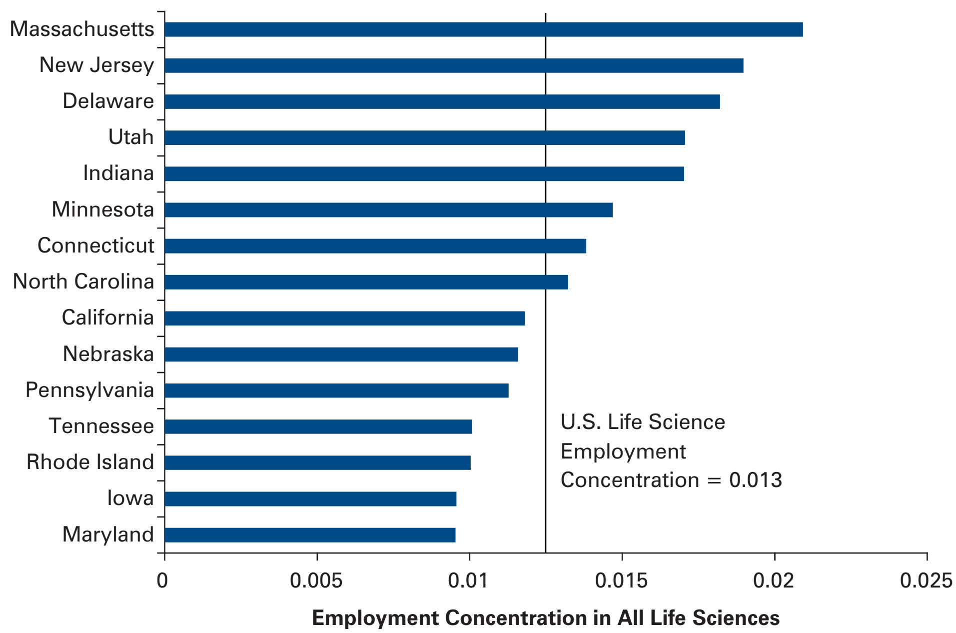
R&D concentrations despite Indiana's patent and research activities. (See sidebar for more detail on the data.)

To summarize, those engaged in R&D are counted in their respective manufacturing industry, be it automotive or chemicals or aerospace, and, as a result, the QCEW data for the all-purpose R&D industry undercounts the number of engineers and scientists (and their activity) in the state.

Consider that another measure of R&D intensity puts Indiana in better light. State data for funds spent on R&D of all types (from the National Science Foundation) divided by statewide employment places Indiana in 13th position, behind Michigan (7), Minnesota (11) and Illinois (12). In other words, the employment concentration data does not allow one to make definitive statements about Indiana's or the Midwest's apparent lack of activity in conducting R&D and innovating.

Figure 2 shows the states with the greatest concentration in life science employment. Indiana ranks well at fifth, but those states ranking higher do so because of a stronger showing in R&D and, in the case of Utah,

■ Figure 2: Top 15 States in Life Science Employment Concentration



Source: IBRC, using Quarterly Census of Employment and Wages data and IBRC estimates for QCEW suppressed data particular strength in surgical and medical instrument manufacturing and medical laboratories.

Conclusion

While Indiana is the 16th-largest state in terms of its economic output and population, the state ranks third in terms of life science manufacturing productivity.

Indiana ranks fifth among states for employment concentration in life science industries. The state ranks 24th in employment concentration in the industry of biotechnology R&D, but this statistic appears to under-report the scientists and engineers who are working in R&D. (They are reported as employed in a life science manufacturing industry.)

It is critical to know Indiana's capacity for, and resources devoted to, R&D. Research and development drives innovation and is critical for future productivity gains. As a result, business leaders and state policy makers would be wise to ensure that activities in manufacturing and R&D are balanced. The creation of the Indiana Biosciences Research Institute (www.indianabiosciences.org), the first industry-led bioscience research institute in the country, will have R&D at the forefront of its mission. That vision and focus should help to ensure that Indiana will remain a leader in the life sciences industry and that the sector will continue to create a dynamic and future-focused economy. ■

Notes

1. Strictly speaking, GDP is equal to all value-added in the economy. Value-added in a strict national income accounting framework can be measured by subtracting the cost of materials, energy and purchased services from revenues (or in this case the value of shipments).
2. Companies represented by NAICS 541712 provide research and experimental development in the physical, engineering, and life sciences, such as agriculture, electronics, environmental, biology, botany, computers, chemistry, food, fisheries, forests, geology, health, mathematics, medicine, oceanography, pharmacy, physics, veterinary and other allied subjects.

For Data Geeks Only

Sometimes data can mislead

The takeaway: ***Employment by industry statistics may misrepresent employment depending on the data set in use. Based on County Business Pattern data, one posits that the Census Bureau 1) places R&D life science workers in the biotech and all-purpose R&D industries and 2) places life science workers at company headquarters in the management of companies industry. The Quarterly Census of Employment and Wages (QCEW) data from the Bureau of Labor Statistics (BLS), on the other hand, appears to place them all in manufacturing. As a result, the QCEW data understates R&D workers and, by extension, the R&D activity in the state.***

An interesting outcome of the federal government's fractured statistical system became evident conducting this analysis. There are several statistical agencies dispersed through the federal departments—for example, the Census Bureau and the Bureau of Economic Analysis are in the Department of Commerce whereas the BLS resides within the Department of Labor. Census, by law, cannot share much of its data with other agencies.

It turns out that Census and the BLS have different establishment lists. An establishment is a location, an address, for a business (or nonprofit or government office). Data for employment and wages, for example, are collected at the establishment level and aggregated by industry, county, state, ownership type, etc. In the main, BLS developed their list based on state workforce agencies' unemployment insurance filings (and not all establishments have to file for unemployment insurance). The Census list is initially derived from the Internal Revenue Service as a source of business information. Census also uses administrative records from the Social Security Administration, in addition to information from the BLS and their own annual Company Organization Survey.

Still awake? There are differences in the collection, scope, data definitions and reference periods for the above sources. One particularly interesting difference is that the definition of an active establishment varies depending on the data set. In the aggregate, the number of BLS and Census establishments differed by about 8 percent in 2001. This difference doesn't consider the degree of overlap between the two lists of some 7 million plus establishments each.

The micro data were compared for the two 2003 establishment lists. Researchers found that for certain sectors, differences in the published data for industry and state combinations may be explained by differences in industry coding of moderately large multi-establishment companies. For example, states could vary in terms of coding a firm's headquarters as a manufacturing establishment or mining establishment. It turns out that multi-establishment businesses, ones that have several activities—manufacturing, logistics, R&D, headquarters, for example—in several locations, can be assigned different NAICS codes in the Census list, but one NAICS code in the BLS list. Moreover, this difference in coding can vary from one state to another.

A single, unified statistical agency that can share data amongst itself, like most other countries have, might be a good idea.

For those who wish to know more about the need for statistical agency data sharing and why it is important, please consult these articles:

Becker, Randy, et al. "A Comparison of the Business Registers Used by the Bureau of Labor Statistics and the Bureau of the Census." Joint Statistical Meetings. 2005.

Fairman, Kristin, et al. "An Analysis of Key Differences in Micro Data: Results from the Business List Comparison Project." U.S. Census Bureau Center for Economic Studies Paper No. CES-WP-08-28, 2008.

Fixler, Dennis, and J. Steven Landefeld. "The Importance of Data Sharing to Consistent Macroeconomic Statistics." In *Improving Business Statistics through Interagency Data Sharing*, edited by Caryn Kuebler and Christopher Mackie, 91-132. Washington, DC: National Academies Press, 2006.