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Has Development Occurred at the Expense of Indiana's Prime Farmland?

Mix of Occupations Impacts Metro Income

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From the Editor

It's summertime and the recession is fading. Well, kind of. Unemployment levels are still high in Indiana and the Midwest. Congress continues to grapple with appropriate responses to the issue of job creation and the continuation of unemployment benefits. And much of the world is watching BP and the United States struggle with the mess in the Gulf of Mexico.

While all of that is happening, we ask you to turn your mind to two important dimensions of the Hoosier economy: land use and the effect of the types of jobs we have on per capita income measures. The first article poses a critical question to Hoosiers—are we using up too much prime farmland for development? The second article hones in on the types of jobs and their wages among Indiana's metropolitan areas. It will come as no surprise that the Indianapolis metro area continues to grow higher paying jobs, particularly among the professional, legal, and life sciences occupations. But, there are rising and sinking stars to be found among all of the metro areas as this article delves into the effect of our occupational mix on personal income.

Has Development Occurred at the Expense of Indiana's Prime Farmland?

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From 1950 to 2007, the proportion of Indiana acreage devoted to farmland has decreased 24 percent (from 84.8 percent to 64.4 percent); meanwhile the population grew by 2.4 million, or 61 percent (see Figure 1).[1] As a large percentage of the loss of farmland tends to occur at the periphery of urban areas, intense debates have occurred about the effects of urban sprawl on Indiana's natural resources. For clarification, urban sprawl is the inefficient land use pattern associated with urban growth and development,[2] and is often characterized by low density development occurring outside of urban areas. Developers argue that they build what people want according to market demands. Indeed, development is spurred by positive economic growth, which is desired in Indiana, but is this development occurring at the expense of Indiana's prime farmland? Additionally, what farmland preservation policies does the state have in place to protect our best farmland? This article will look at the state's agricultural trends, the distribution of prime farmland in Indiana, and projected urban growth patterns to address these important issues.

Importance of Agriculture to Indiana

The Indiana agriculture industry is a large contributor to our state's economy at an estimated $25 billion a year.[3] Not only is Indiana ranked in the top ten in sales volume for corn, soybeans, poultry, hogs, as well as milk and other dairy products, the agriculture industry comprised roughly 17.6 percent of the state's exports with a value of $5.3 billion in 2008. For an industry that only employs 4.5 percent of Hoosiers, the output is quite impressive.[4]

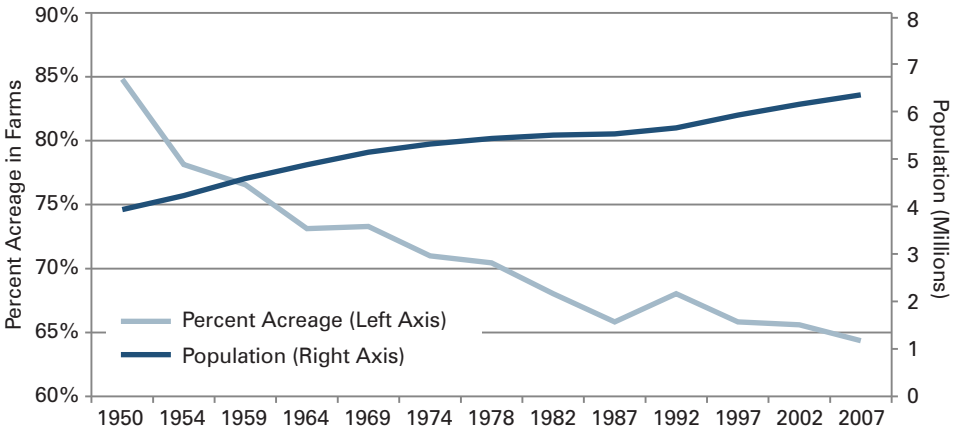
To give perspective on which counties are the leading producers of various commodities, **Figure 2** shows the top ten counties for producing field corn, soybeans, wheat, hay, popcorn, vegetables, fruits, cut Christmas trees, cattle (beef and dairy), hogs, sheep, poultry (chickens and turkeys), and goats. As expected, some counties are "super-producers" and are ranked in the top ten for numerous commodities. These include Elkhart County (a top ten producer for seven commodities), Washington County (seven commodities), LaGrange County (six commodities), and Adams County (five commodities).

Prime Farmland in Indiana

The U.S. Department of Agriculture (USDA) defines prime farmland (Capability Class I and II) as land best suited to food, feed, forage, fiber, and oilseed crops. This land has the soil qualities, growing season, and moisture supply needed to economically produce a sustained high yield of crops. Therefore, prime farmland produces the highest yields with minimal inputs of energy and economic resources, resulting in the least damage to the environment. The loss of prime farmland to other uses (i.e., urban development) forces the producer to use marginal lands, which typically are more erodible, more prone to drought, less productive, and not as easily cultivated for field use.[5] In order to make marginal lands more productive, operators would need to apply more inputs such as water, chemicals and fertilizers, tile (for drainage), and other technologies, which affects the operator's bottom line and could impact the environment.[6]

In 1997, the United States had a total of 331.9 million acres in prime farmland, a decline of 13.6 percent from 1977.[7] In Indiana, 56.4 percent of our farmland, or 12.9 million acres, was defined as prime farmland, making Indiana one of the three

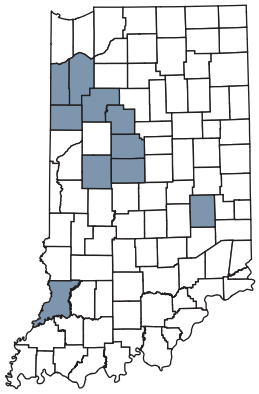
FIGURE 1: Percentage of Indiana's Acreage in Farms and Population, 1950 to 2007



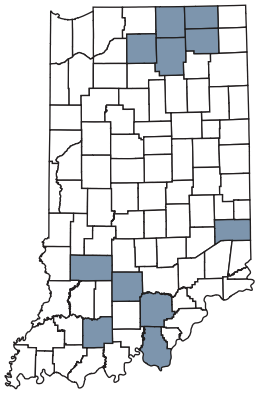
Notes: Differences in time intervals are due to the Census of Agriculture being taken every ten years prior to 1950. After that, the Census was taken every four or five years until 1982 where it now occurs every five years.
Source: IBRC, using USDA Census of Agriculture and U.S. Census Bureau data

Figure 2: Top Ten Producing Counties of Agriculture Commodities

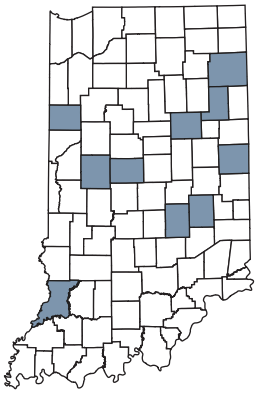
Corn *(bushels)*
2009



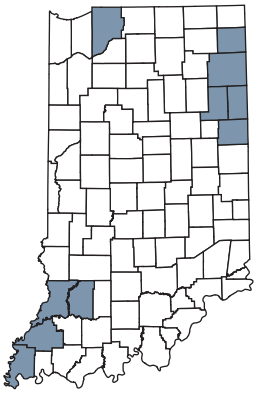
Hay* *(tons)*
2008



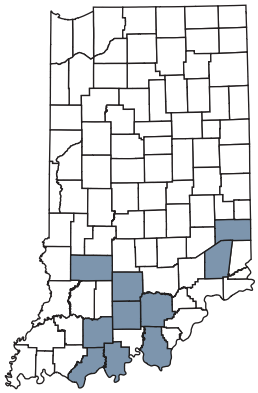
Soybeans *(bushels)*
2009



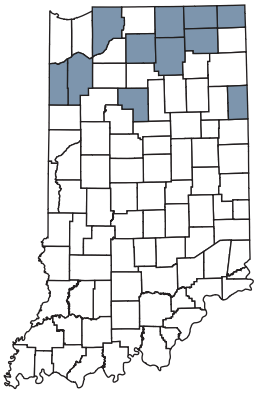
Wheat *(bushels)*
2008



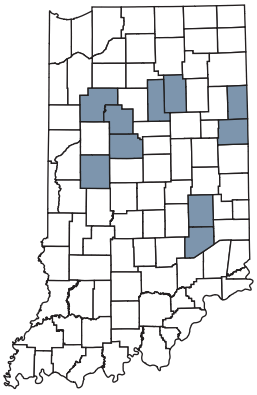
Beef Cows *(head)*
2010



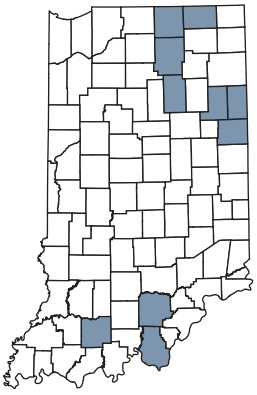
Milk Cows* *(head)*
2010



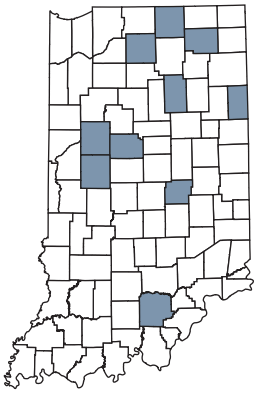
Hogs *(head)*
2007



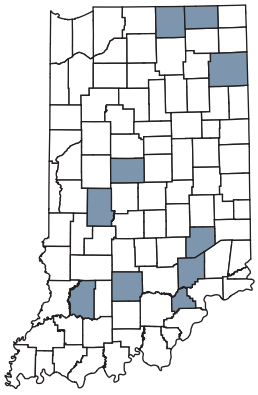
Chickens *(layers, broilers, and pullets)*
2007



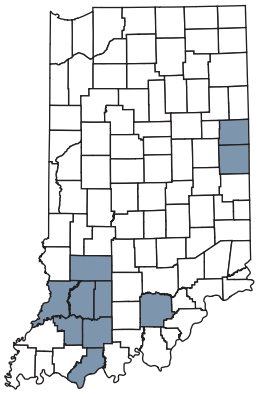
Lambs *(head)*
2007



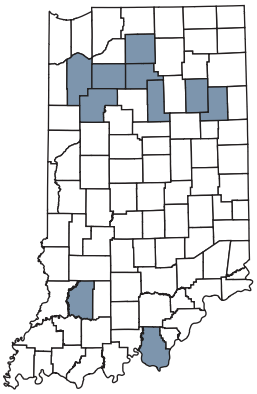
Goats *(head)*
2007



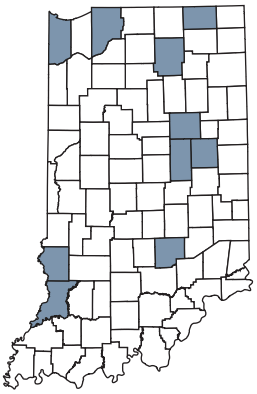
Turkeys *(head)*
2007



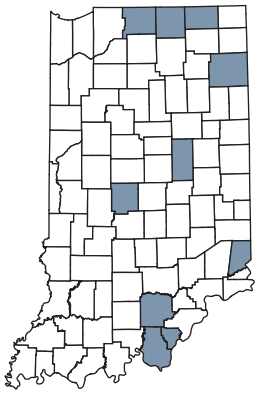
Popcorn *(pounds)*
2007



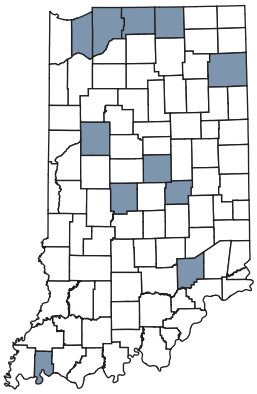
Vegetables *(acres)*
2007



Fruit *(farms)*
2007



Christmas Trees* *(farms)*
2007



For detailed maps of where commodities are produced in Indiana, see the interactive version of this figure online at www.ibrc.indiana.edu/ibr

*Eleven counties are shaded due to a tie in production of the counties ranking tenth.

Sources: IBRC; Most data came from the Indiana Agricultural Statistics 2008-2009 and reflect 2008 data, except corn, soybeans and wheat which reflect 2009 data from the National Agricultural Statistics Service (NASS). Beef and milk cows as of inventory in January 2009 data also came from the Indiana Agricultural Statistics Office (NASS). Data for vegetables, fruits, and Christmas trees came from the 2007 Census of Agriculture and are provided in acres and number of farms due to the amount of non-disclosable data. All other animal data came from the 2007 Census of Agriculture Report.

states to have over 50 percent of its farmland area classified as prime farmland, behind Iowa (66.3 percent) and Illinois (58.7 percent).[8] **Figure 3** shows that the counties with total land area classified as over 80 percent prime farmland are mostly clustered in north-central Indiana up to the northeastern corridor of the state.

Unfortunately, as noted by researcher Arthur Nelson, most of the United States' prime farmland is located within the suburban and exurban counties of metropolitan areas.[9] Therefore, the land that is most suitable for agricultural production tends to be equally desirable for development.[10] This was seen between 1992 and 1997 when Indiana saw 144,000 acres—86.3 percent of that classified as prime farmland—converted to developed uses.[11] Regrettably, these lands that are developed are likely to never be reconverted to agricultural uses.[12]

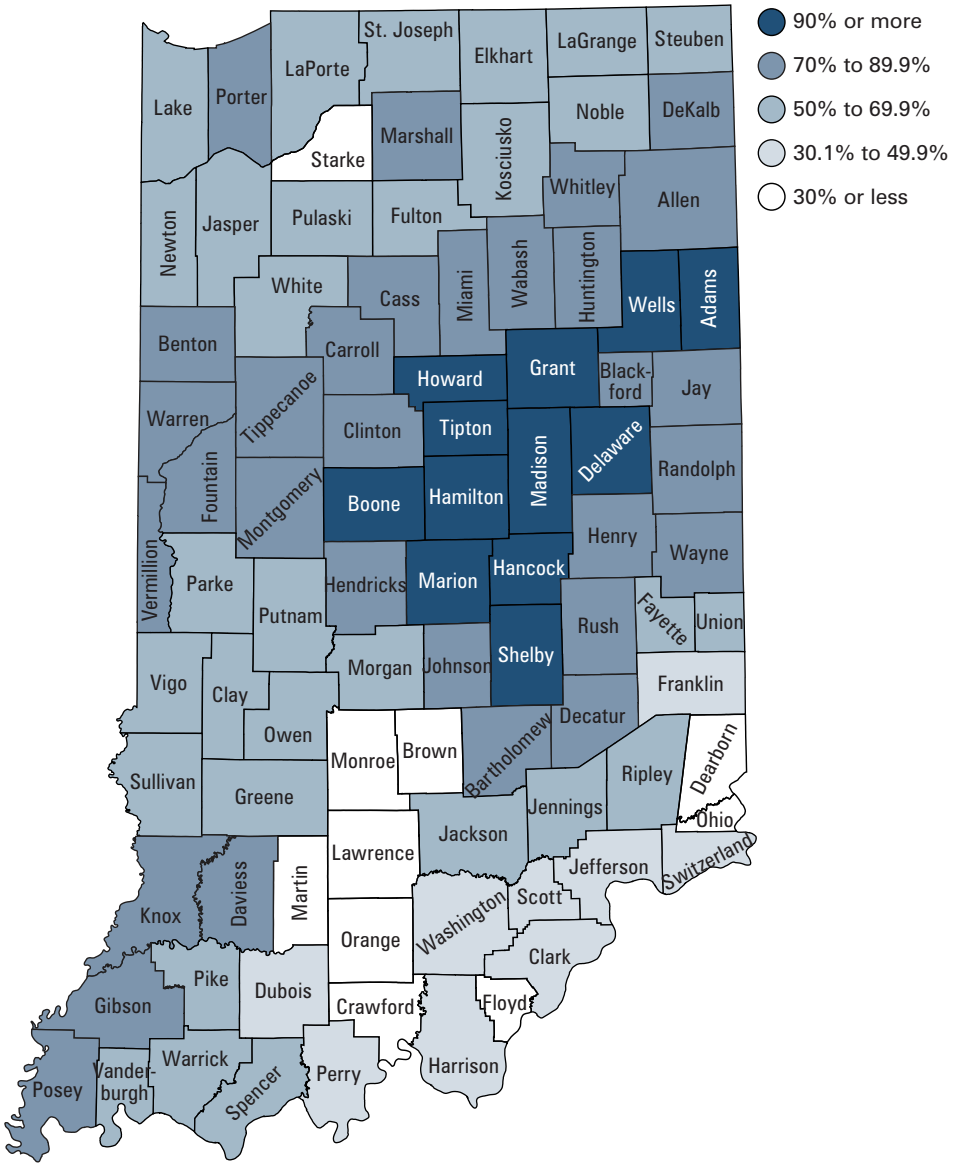
Past, Current, and Projected Growth in Central Indiana

For the remainder of the article, focus will be directed to the central Indiana region of forty-four counties (see **Figure 4**) that are dispersed within six Economic Growth Regions (EGRs) as defined by the Department of Workforce Development (DWD). Of these counties, 23 (52.3 percent) have 80 percent or more of their land area classified as prime farmland. Twelve counties have between 60 and 79.9 percent of their land area as prime farmland, with the remaining nine counties at less than 60 percent.

Between 1950 and 2009, it is estimated that Indiana's total population grew 63 percent and the forty-four county region's growth rate was 72 percent. However, the counties surrounding Indianapolis (Boone, Hendricks, Morgan, Marion, Johnson, Shelby, Hancock, and Madison) led the regions with a growth rate of 108 percent. The county with the most explosive growth was Hamilton (880 percent) followed by Hendricks and Johnson counties (472 percent and 440 percent, respectively), as shown in **Figure 5**.

Due to the surge in population, the population density has also increased dramatically (see **Table 1**). Within the forty-four county region, those counties in regions 5, 8, and 9 have grown between 16 to 38 percent from 1980 to 2009, yet doubled or nearly doubled their population density since 1950. Again, Hamilton County lead the way, increasing its population density from 206.1 people per square mile in 1980 to 701.8 people per square mile in 2009. In conjunction with the population growth, counties also saw an increase in housing units and other developed parcels of land devoted to businesses and public infrastructure. The state's official population estimates for the years 2005 to 2040 produced by the Indiana Business Research Center show that Region 5 will continue to

FIGURE 3: Percentage of County Land Area Classified as Prime Farmland

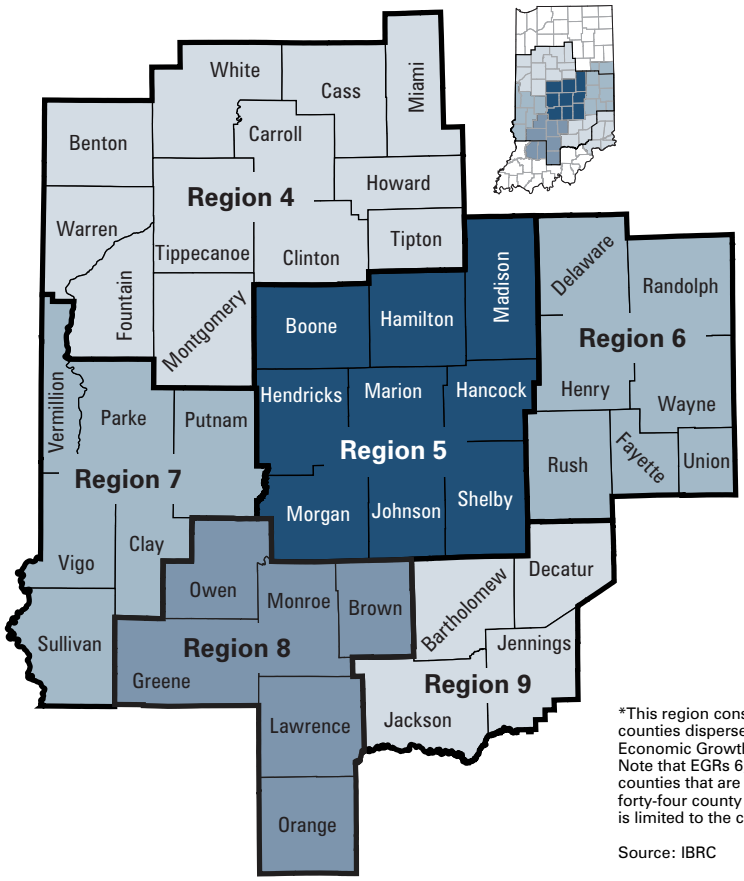


Note: These percentages are based on total land area.
Source: IBRC, using STATSGO data (1994 National Cooperative Soil Survey, USDA)

grow at a fast clip of 31.3 percent (see **Figure 6**). Hamilton and Hendricks counties will continue to dominate the population growth with 84 percent and 54 percent growth between 2005 and 2040.

The maps in **Figure 7** display today's land use and projected land use change through 2040. The Center for Urban Policy and the Environment at Indiana University–Purdue University Indianapolis created the *luci2 Urban Simulation Model* that projects development

FIGURE 4: Central Indiana Region*



*This region consists of forty-four counties dispersed among six Economic Growth Regions (EGRs). Note that EGRs 6, 8, and 9 contain counties that are not included in this forty-four county region. All analysis is limited to the counties shown.

Source: IBRC

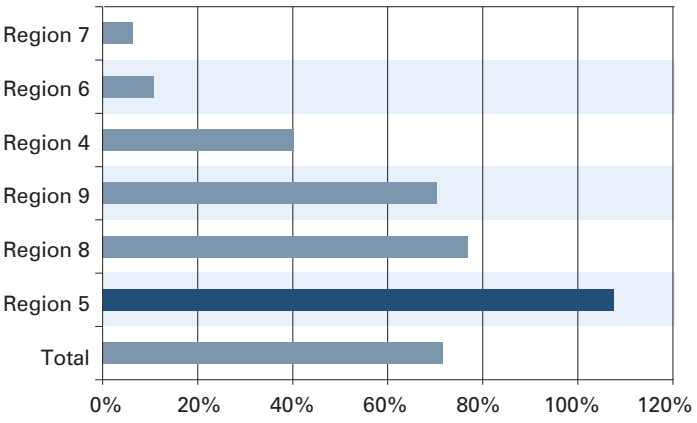
TABLE 1: Population Density, 1980 and 2009

Area	1980	2009
Breakdown of 44-County Region		
Average	155.8	189.5
Region 5	383.5	528.0
Region 6	134.2	119.5
Region 8	88.1	107.9
Region 9	89.1	102.9
Region 4	96.3	101.4
Region 7	94.0	93.6
Breakdown of Region 5		
Marion	1,931.2	2,248.3
Hamilton	206.1	701.8
Johnson	241.2	441.9
Hendricks	170.9	344.3
Madison	308.2	290.7
Hancock	143.5	223.2
Morgan	127.9	174.4
Boone	83.8	133.1
Shelby	96.7	107.8

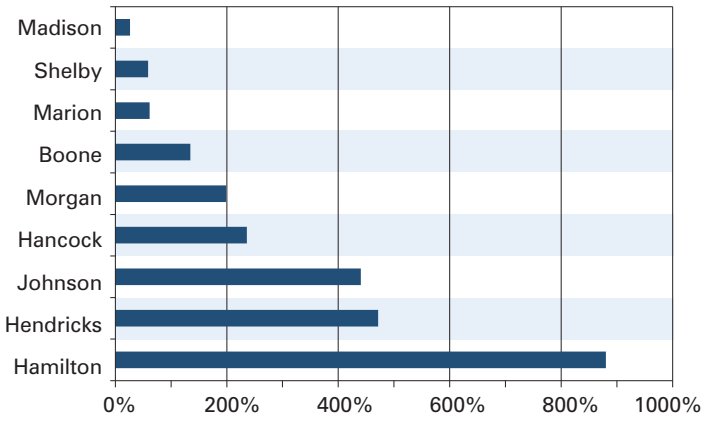
Source: IBRC, using U.S. Census Bureau data

FIGURE 5: Population Growth Trends, 1950 to 2009

BREAKDOWN WITHIN 44-COUNTY REGION



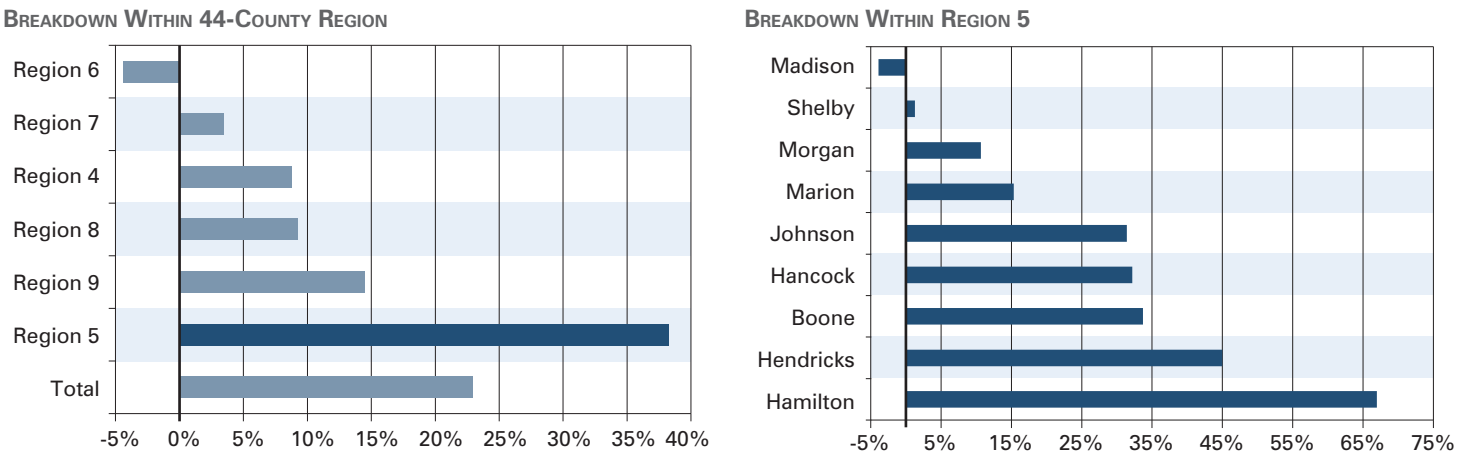
BREAKDOWN WITHIN REGION 5



Source: IBRC, using U.S. Census Bureau data

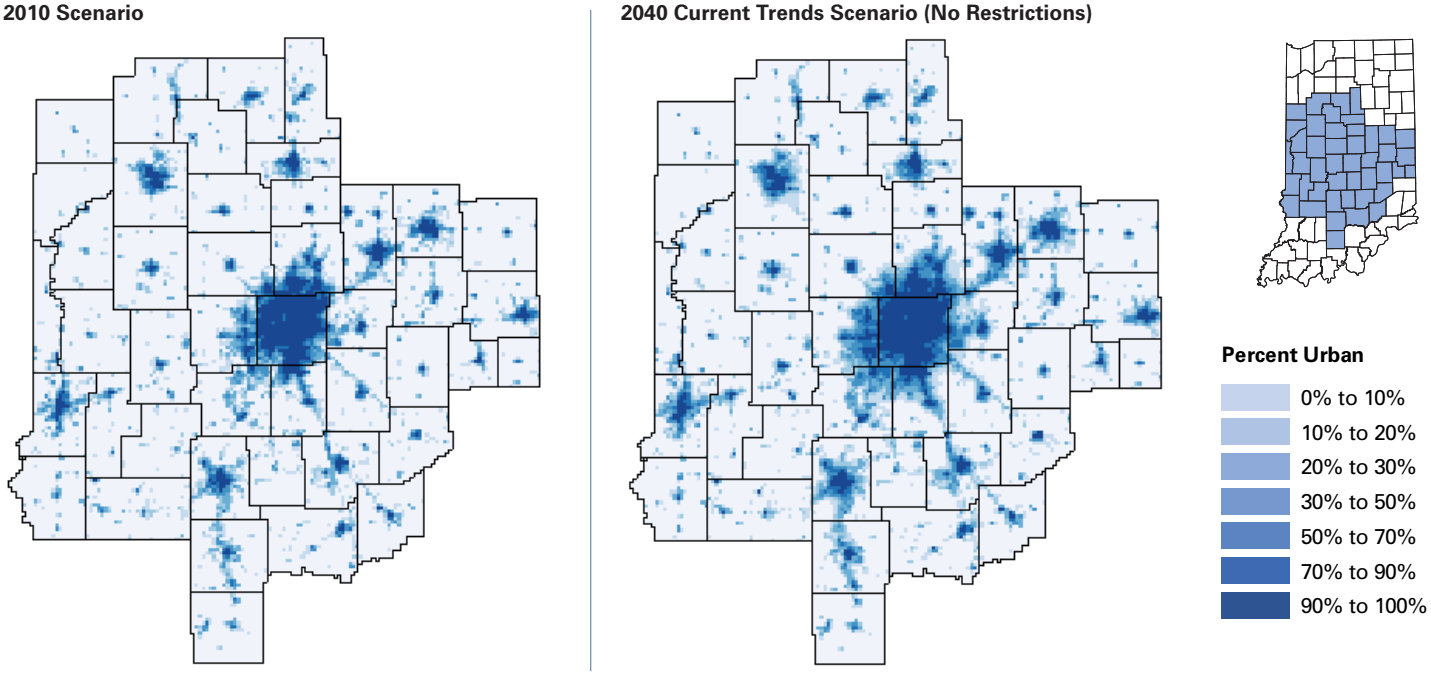
scenarios in the central Indiana region, using 2000 data as the base model.[13] The maps for 2010 and 2040 utilize the IBRC population projection data to project the urban growth areas. Comparing these maps, one can see that the Indianapolis metropolitan area is projected to spread further into the counties surrounding Marion County. Outlying areas with prior urban development will also continue to grow and expand. This expansion of urban areas equates to nearly 500,000 acres being converted to urban lands between 2000 and 2040. Of this figure, slightly more than 270,000 agricultural land acres would be converted (54.1 percent), which means an average loss of 6,752 acres per year. This would equate to a loss of at least 28 farms a year (using the 2007 average farm size of 242 acres), for a total loss of 1,116 farms or more. Unfortunately, roughly 68 percent of this farmland loss will be in areas with high amounts of prime farmland (greater than 80 percent), which makes the loss of farmland even more significant.

Figure 6: Projected Population Growth, 2005 to 2040



Source: IBRC

Figure 7: Land Classified as Urban in Central Indiana under Current Trends, 2010 and 2040



Source: IBRC, using Center for Urban Policy and the Environment data

Smart Growth and Indiana Farmland Preservation Policies

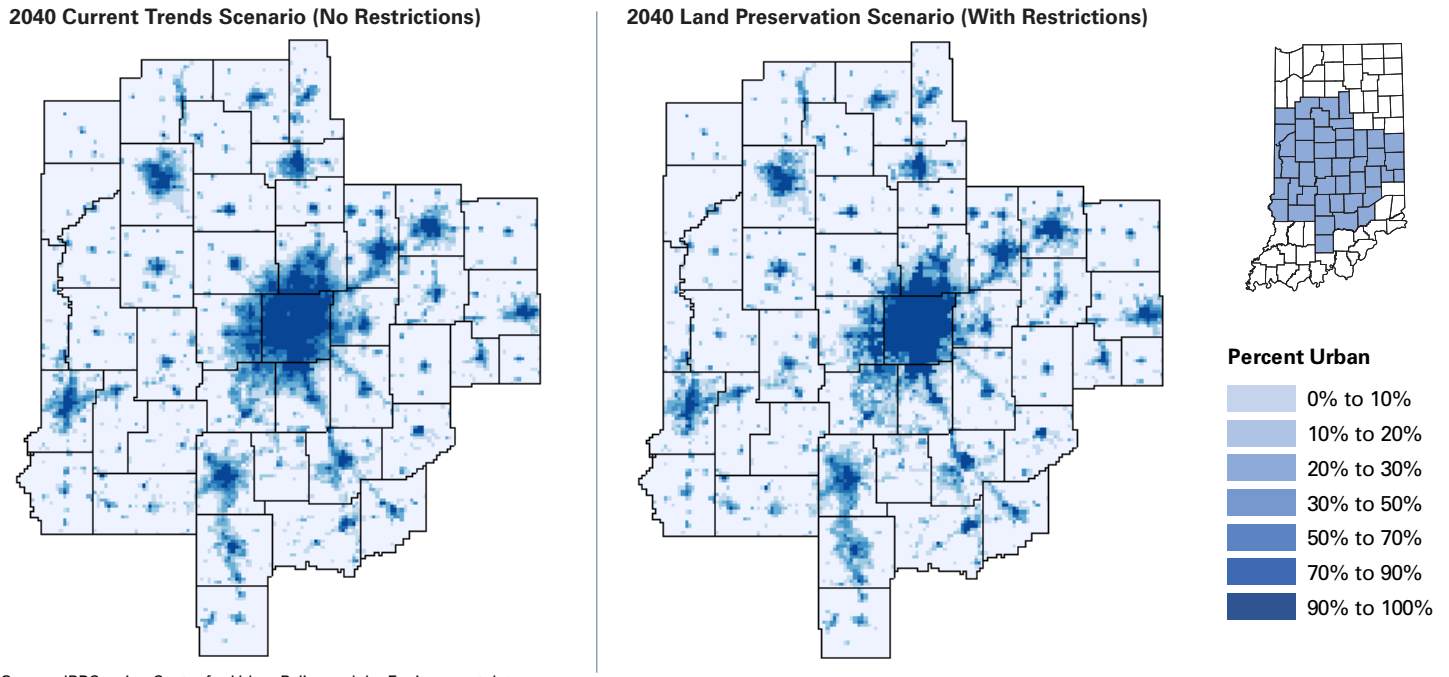
Since the mid-1990s, "smart growth" has become a popular term for how to combat urban sprawl and compact development while preserving rural lands. Unfortunately, smart growth is difficult to define due to its various potential elements, which can include adoption of fiscal resource sharing amongst localities; promotion of compact, mixed-used development; and preservation of open space. The opposite of smart growth can be more broadly defined as sprawling, haphazard, and poorly planned development in the outer suburbs and exurbs that also dilute the economic and social vitality of cities and older suburbs.[14]

The movement to preserve privately held land began in the 1980s after the federal government's relaxed environmental laws and reduced federal land acquisition programs, spurring the increase in private nonprofit land trusts. The rise in land trusts also grew due to frustrations with communities' rapid pace of growth and the ineffectiveness of local planning to protect important landscapes and natural resources.[15] Indiana currently has a Nature Conservatory and twenty-five different land trusts that purchase land and conservation easements to buffer habitats they don't want developed, including some farmland. While helpful, these programs still do not entirely address the issue regarding the loss of prime farmland near metropolitan areas.

Presently, Indiana does not have statewide farmland preservation policies in place to address the rapid growth of urban and low density development onto prime farmland. However, Indiana does have the Indiana Land Resources Council (ILRC) that provides assistance to counties regarding planning and zoning ordinances. A recent initiative that the ILRC has been working on is agricultural zoning that assists communities with implementing regulations that help strike a balance between competing land uses. This is a critical initiative as seventy-nine of the state's ninety-two counties have different planning and zoning ordinances, several of which may be dated. The remaining thirteen counties have no traditional regulations in place. The ILRC looks at agricultural zoning from an economic and fiscal standpoint that shows that it is optimal to keep farmland (especially prime farmland) in agricultural production and why it's important to keep agriculture in the community development plan. While this approach may be considered non-traditional compared to other states' farmland preservation policies, planning and zoning are critical cornerstones that need to be in place before the state (or county) pursues conservation policies.[16]

Critics of land preservation policies argue that the land market should dictate the rate of development; however, the land market has repeatedly failed to create satisfactory land use patterns. Instead, since land markets are influenced by public infrastructure investments in roads, schools, and sewer

Figure 8: Impact of Development Restrictions on Land Classified as Urban, 2040



Source: IBRC, using Center for Urban Policy and the Environment data

and water facilities, and by local governments whose primary interest is to expand the property tax base, the land markets have encouraged residential and commercial sprawl. A local government's interest in expanding the property tax base over land preservation policies is often misguided as numerous cost-of-community-services studies done by the American Farmland Trust show that residential development demands more in public services than it generates in property taxes, whereas farmland generates more in property taxes than it demands in services.[17] This fall, Indiana voters will have the opportunity to reinforce this paradigm if property taxes are capped at 1 percent, 2 percent, and 3 percent for residential, rental and farmland, and other business establishments, respectively.

The *luci2* model allows for policy changes such as the development of new interstates and restrictions on sensitive lands. To visualize how development would change in central Indiana if restrictions were imposed on agricultural and sensitive land, another map was created that imposed development restrictions on agricultural land, wetlands, and forests (see **Figure 8**). The following conditions were applied that restricted development on: 1) wetlands greater than 20 acres; 2) forested areas greater than 20 acres; and 3) areas with at least 50 percent of land devoted to agriculture production (would keep 75 percent of that area in agricultural production). With this protection, slightly more than six million acres are restricted from development with the majority in agricultural land (75.4 percent). As expected, development on agricultural lands will still occur, just not as intensely as in the previous current trends scenario. The map shows that intense development is kept closer to the core of urban areas, and the percentage of acres in urbanized areas in Hamilton, Hendricks, Hancock, Boone, and Shelby counties decreases, albeit slightly.

Conclusion

Indiana is fortunate to have slightly more than 56 percent of all its farmland classified as prime farmland, a contributing factor to the state's abundant agricultural production. In fact, many individuals have the mindset that there is not a shortage of farmland, thus no need to be concerned about the loss of farmland to development. This mindset could be reinforced by data showing that Indiana has continued to increase its agricultural production while losing farmland. Indeed, the agriculture industry has adapted to the loss of farmland through the growth of small (one to nine acres) and large (greater than 2,000 acres) farms between 1987 and 2007 (78.5 and 80.2 percent, respectively). However, some of the state's most desirable land near metropolitan areas is in a tug of war between agricultural production and development. The state's farmland is a limited natural resource and, once converted to development, is unlikely to be reconverted to agricultural use in the future. Therefore, it is necessary to carefully guide the development around metropolitan areas to preserve prime farmland, while recognizing that the agricultural industry is a large contributor to our state's economy. How this challenge is addressed does not have a direct solution, but the ILRC is approaching this challenge through agricultural zoning, which will help communities better protect and understand the value that agricultural land brings to Indiana's state and local economies by managing urban development in a smart way.

Endnotes

1. Farmland data reflect the 1950 and 2007 Census of Agriculture reports and the population data is derived from the 1950 Census and population estimates for July 1, 2007. National Resources Inventory data would have been used if the data were more recent than 1997. It is believed that the NRI analysis is more accurate than Census data; for more information, see note 12.
2. R. K. Olson and T. A. Lyson, *Under the Blade: The Conversion of Agricultural Landscapes* (Boulder, CO: Westview Press, 1999).
3. See www.in.gov/isda/files/AEDI_Phase_II_Exec_Summ.pdf.
4. For more details about agriculture's contribution to the state's economy, please see Tanya Hall, "The Importance of Indiana Agriculture," *InContext*, May-June 2010, www.incontext.indiana.edu/2010/may-june/article3.asp.
5. Definition obtained from the Indiana Soil Surveys (division of USDA's Soil Conservation Service), accessed at http://soils.usda.gov/survey/online_surveys/indiana/index.html.
6. A. Altshuler, *The Urban Transportation System: Policies and Policy Innovation* (Cambridge, MA: Joint Center for Urban Studies, 1979).
7. Data came from the National Resources Conservation Service (NRCS), Natural Resource Inventory 1997 and D. R. Vining, K. Bieri, and A. Strauss, "Urban encroachment on prime agricultural land in the United States," *International Regional Science Review* 2, no. 2.
8. Data came from NRCS, Natural Resource Inventory 1997 and 1990 Census (for land area).
9. A. Nelson, "Economic Critique of U.S. Prime Farmland Preservation Policies," *Journal of Rural Studies* 6, no. 2 (1990): 119-142.
10. B. Solomon, "Farmland Protection: A Case of Quality Not Quantity," *Land Use Policy* (October 1984): 357–66.
11. Farmland Information Center on Indiana Statistics derived from the National Resources Inventory (NRCS).
12. A. Thompson and L. Prokopy, "Tracking Urban Sprawl: Using Spatial Data to Inform Farmland Preservation Policy," *Land Use Policy* 26 (2009): 194–202.
13. The *luci2* model can be found at http://luci.urbancenter.iupui.edu/default.asp.
14. T. Daniels and M. Lapping, "Land Preservation: An Essential Ingredient in Smart Growth," *Journal of Planning Literature* 19 (2005): 316–329.
15. See note 14.
16. Information obtained from Executive Director Sarah Simpson via interview. More information about ILRC and agricultural zoning can be found at www.in.gov/isda/2339.htm.
17. See note 14.

Mix of Occupations Impacts Metro Income

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Indiana's per capita personal income (PCPI) was 86 percent of the PCPI for the United States as a whole in 2008. PCPI in the Indianapolis metro area, on the other hand, was 98 percent of the nation. Why is the Indy area doing so much better than Indiana?

Recent IBR articles have explained Indiana's lackluster personal income performance compared to the nation.[1] This article expands on that research to show that the occupational mix in Indiana's metro areas explain the differentials in PCPI across the state.

Figure 1 shows the share of total employment in the higher-earning occupations for Indianapolis, Indiana, and the United States. There are some striking differences. With the exception of the health care practitioner and technical occupations group, every top-tier occupation category is represented more highly in Indianapolis and the United States than in Indiana as a whole. While earnings in these top-tier occupation categories are generally higher in the nation than in Indianapolis, the metro has a similar wage and concentration advantage over the state in these higher-earning occupation categories. The extent to which Indianapolis mirrors the nation, and differs from the state, both in terms of earnings and concentration of higher-earning occupations suggests that the answer for Indiana's PCPI problems might lie in these occupations.

Figure 2 presents the same geographic comparison for middle-tier occupation categories. These occupations do not show nearly as uniform a pattern, but one category can be easily differentiated from the rest—production occupations. At 13 percent of Indiana employment,

Figure 1: Indianapolis Higher-Earning Tier Comparison, 2008

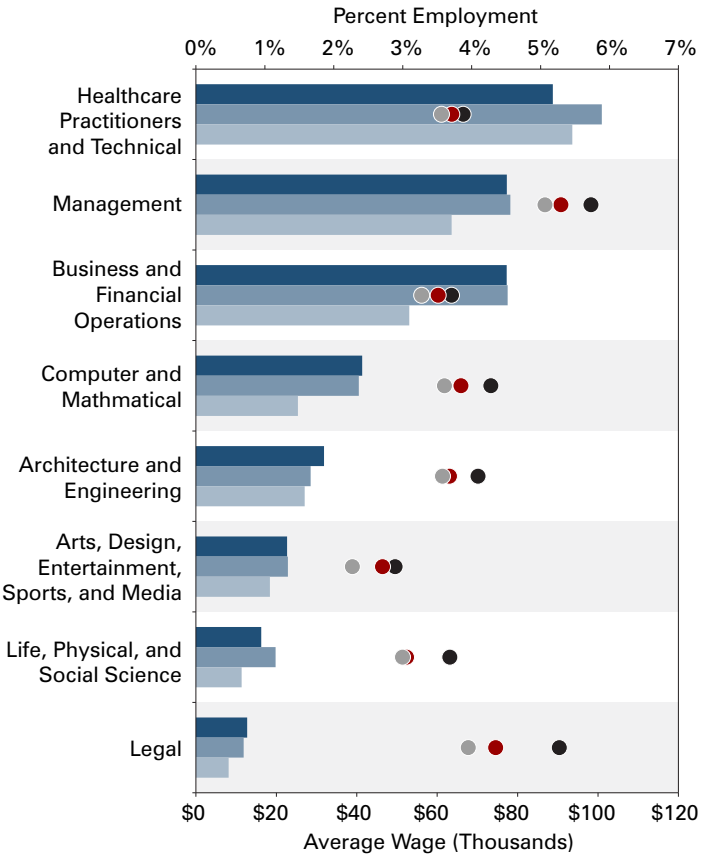
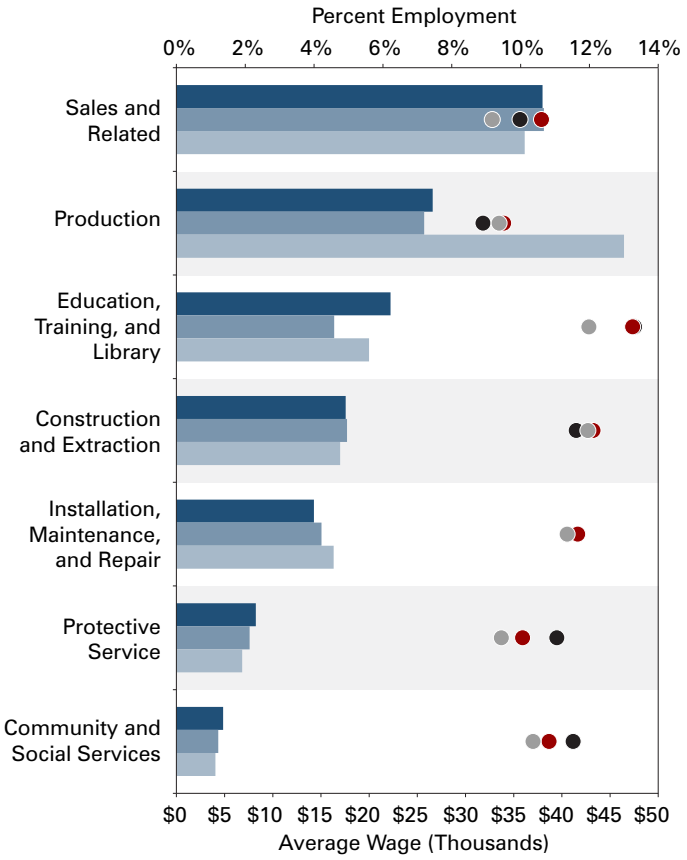


Figure 2: Indianapolis Middle-Earning Tier Comparison, 2008



Legend (Figures 1 and 2)
Percent Employment (Top Axis) United States, Indianapolis, Indiana
Average Wage (Bottom Axis) United States, Indianapolis, Indiana

Source: IBRC, using data from the Bureau of Labor Statistics data

the concentration of production occupations in the state is almost double that in Indianapolis and the United States. The state's average production wage is below that in Indianapolis and, as a result, the heavy concentration does not help in terms of average overall wage for the state. Again, Indy's advantage seems to come from a concentration in higher-earning occupations.

To gain a stronger grasp of what is driving the discrepancy between PCPI across the state, consider two other metropolitan statistical areas (MSAs): Fort Wayne and Columbus. Fort Wayne's concentration and average wage for the top-tier occupations are pictured in **Figure 3**, alongside those for Indiana and the United States. Fort Wayne's PCPI is just barely below the Indiana average, 85 percent of the nation's PCPI. Again, with the exception of the health care practitioner and technical occupations group, all top-tier occupation categories show Fort Wayne and Indiana with lower concentrations than the nation. Just as in Indianapolis, the U.S. average for wages in these occupation groups are materially greater than in Indiana and Fort Wayne. Thus, Fort Wayne and the state as a whole are at a disadvantage in terms of the concentration and the average wage of the higher-earning occupations.

Figure 4 compares the middle-tier occupations for Fort Wayne against the nation and the state. Specifically, the Fort Wayne MSA shares Indiana's high concentration of production occupations. Unlike the top-tier occupations, there is a small discrepancy in average wage for these occupations between Fort Wayne and Indiana.

Columbus' PCPI sits between Fort Wayne and Indianapolis. In 2008, it was 95 percent of U.S. PCPI, beating the state average by 9 percentage points. **Figure 5** shows the higher-earning, top-tier occupations for Columbus. The story is more analogous to Indianapolis than to Fort Wayne. It is clear from **Figure 5** that Columbus' advantage derives predominantly from two occupation categories: management and engineering. The architecture

Figure 3: Fort Wayne Higher-Earning Tier Comparison, 2008

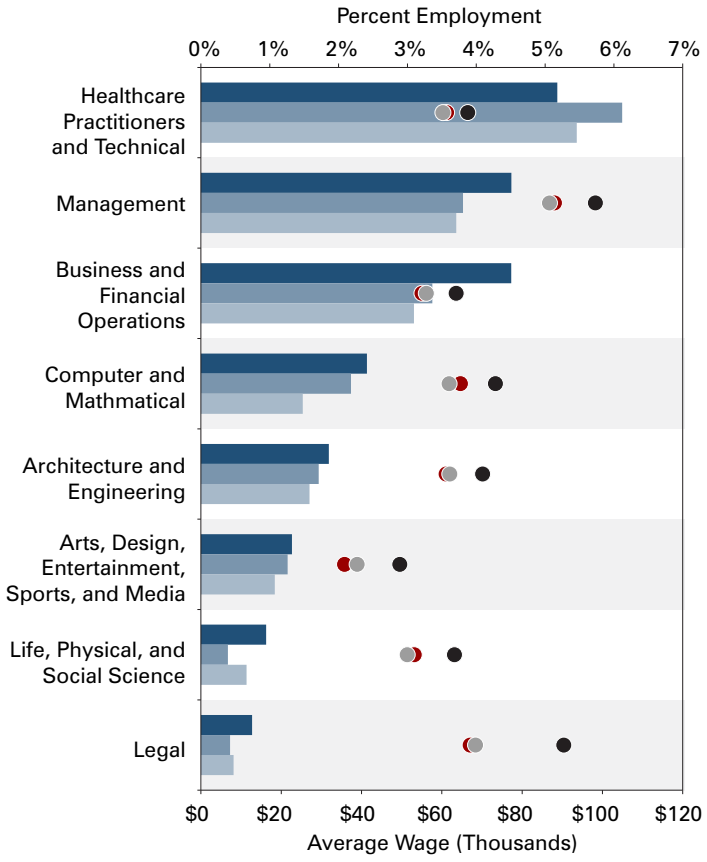
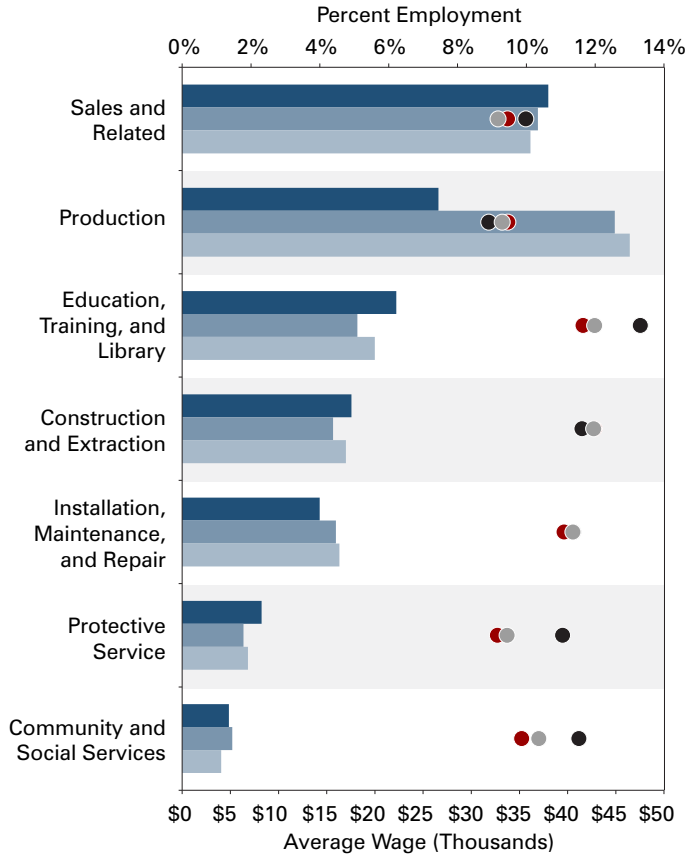


Figure 4: Fort Wayne Middle-Earning Tier Comparison, 2008



Legend (Figures 3 and 4)

Percent Employment (Top Axis): United States, Fort Wayne, Indiana

Average Wage (Bottom Axis): United States, Fort Wayne, Indiana

Source: IBRC, using data from the Bureau of Labor Statistics data

and engineering category, especially, dwarfs the nation and Indiana in concentration, with an average wage slightly above the Indiana average. To put this in perspective, the concentration of architecture and engineering occupations in Columbus is more than three times the concentration in Fort Wayne. In addition, the average wage for management occupations in Columbus is well above Indiana's average, and just slightly below the U.S. average.

Figure 6 introduces a countervailing force, which is its concentration of production jobs at more than 20 percent of total employment. Even so, the high concentration of top-tier jobs exerts great influence over Columbus' average wage. In Columbus, the contribution to average wage from top-tier jobs is $15,577, 9.2 percent higher than the contribution for middle-tier jobs. For comparison, consider that in Fort Wayne, top-tier jobs contribute $12,348 to the average wage, 15.4 percent below the contribution from middle-tier jobs. Columbus is yet another example of how top-tier occupations can help to lift average income.

In our previous article on the occupational dynamics that drive Indiana's lagging PCPI, we concluded that the main culprit is Indiana's relatively low concentration of higher-earning occupations and the lower earnings of those occupations. In this article, we suggest why the PCPI of Indianapolis is about the same as the nation as a whole—the occupational mix of Indy looks like the occupational mix of the nation. Comparing Columbus and Fort Wayne's occupational mixes against the state and national averages both helps to explain their relative PCPI performance and bolsters the case that Indiana's lackluster income performance can be explained by the relative dearth of jobs in higher-earning occupations.

Note

1. See Andy Zehner, "Five Hundred Reasons Hoosier Incomes Trail the Nation," *Indiana Business Review* 84, no. 3 (2009), www.ibrc.indiana.edu/ibr/2009/fall/article2.html and Timothy F. Slaper and Ryan A. Krause, "Occupational Hazard: Why Indiana's Wages Lag the Nation" *Indiana Business Review* 85, no. 1 (2010), www.ibrc.indiana.edu/ibr/2010/spring/article1.html.

FIGURE 5: Columbus Higher-Earning Tier Comparison, 2008

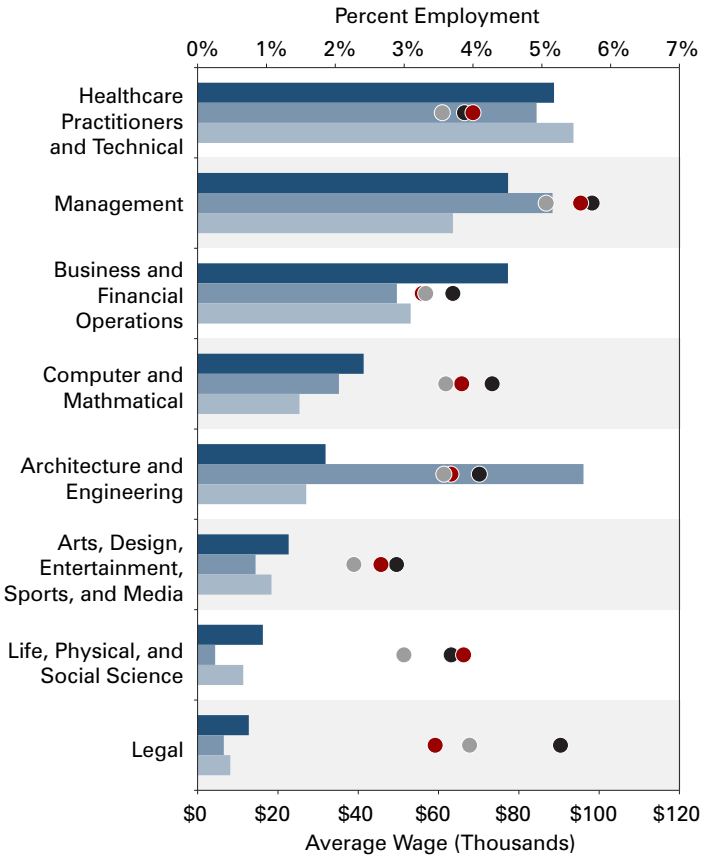
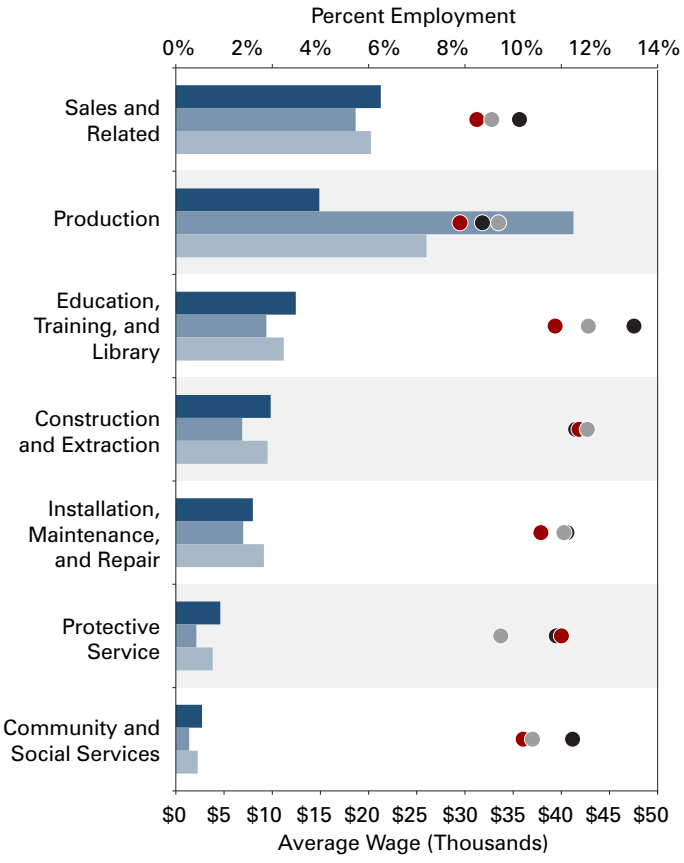


FIGURE 6: Columbus Middle-Earning Tier Comparison, 2008



Legend (Figures 5 and 6)

Percent Employment (Top Axis): United States, Columbus, Indiana

Average Wage (Bottom Axis): United States, Columbus, Indiana

Source: IBRC, using data from the Bureau of Labor Statistics data

Ion Drive: A Visit to EnerDel[1]

Timothy F. Slaper: Director of Economic Analysis, Indiana Business Research Center, Kelley School of Business, Indiana University

It seems apparent that removing oil dependency from our economy will require removing the gas tank from cars and that batteries will largely replace those gas tanks. The type and source of those batteries, however, remains an open question. Will the United States become as dependent on importing batteries from Asia as it is dependent on importing oil now? Perhaps not. Indiana is home to EnerDel, the only U.S. manufacturer producing commercial-scale, automotive-grade lithium-ion battery systems. The company formed when Ener1 (its parent company) acquired the lithium-ion battery operations of Delphi Corporation. Its goal is to obviate the need for gasoline to power vehicles, either by reducing the gasoline required for operation via hybrid electric vehicles (HEV) and plug-in hybrids (PHEV) or by eliminating the need for gasoline entirely with fully electric vehicles (EV). The goal for the latter vehicle, charging in as little as fifteen to twenty minutes a day, is in sight, subject to the availability of fast-charging stations. This article provides an inside view of EnerDel, based on a personal visit.

Most lithium-ion battery manufacturing in the United States is limited to the assembly of bulky battery packs. These manufacturers import their batteries from Asia, bundle them into big boxes, and then adapt the software and electronics to integrate the battery packs into the vehicle. EnerDel, on the other hand, offers fully integrated electric power systems with the components largely manufactured in the United States.

EnerDel has two plants just north of Indianapolis. When I met Derrick Buck, director of battery system integration, I was checking out a prototype hydrogen-electric hybrid car. The car sat next to a stand reminiscent of the old-style gasoline pump, the uncluttered, slender iconic ones from the early days of the internal combustion engine, with a hose draped on one side. The hose in this case is a high-voltage electric cord. "With that charging station, we can recharge this vehicle in about eighteen minutes," says Buck. Buck is a Purdue University graduate and a fourth-generation auto engineer. Like the other two engineers I would meet that day, he is a Hoosier with decades of experience in the auto industry.

Buck gave me an overview of EnerDel's lithium-ion battery pack, which differs from the nickel metal hydride (NiMH) batteries used on earlier models of HEVs. The lithium-ion was chosen for several reasons. Lithium is the third lightest element and the lightest metal. It provides superior energy and power density. The development of the lithium-ion battery over the last two decades revolutionized the mobile phone industry. Without dramatically smaller size and cost, it is unlikely the ubiquitous cell phone would have gained widespread adoption.

Right out of the gate, it was clear that product design, capabilities, and manufacturing were difficult to tease apart. "We integrate multiple chemistries for specific applications with a prismatic cell design and stacking architecture for superior performance, longevity, and safety," Buck explains. "Not only do we get better energy density, but these vehicular batteries are superior in safety and dependability." EnerDel's battery chemistry has led to improved battery stability and overcoming the thermal problems that occurred in earlier vintages of lithium-ion batteries. The batteries can also work dependably over a broad range of temperatures, currently as cold as -22 degrees Fahrenheit.

Many Advantages

Combined with computer and electronic hardware and software, the lithium-ion chemistry is capable of quick acceleration, regenerative braking (transferring the braking energy back into the vehicle battery) and longer range. Adjusting the chemistry, hardware, and software also provides the manufacturer the flexibility to make batteries for specific applications. The energy needs for electric vehicles are not one-size-fits-all. HEV cells focus on power, providing ultra-high discharge capacity, with more than a 50 C-rate continuous discharge possible (meaning an entire battery would discharge in just over a minute). EV cells, on the other hand, offer higher energy density for longer range combined with good power characteristics.

In addition to advances in battery chemistry, EnerDel cells have prismatic design, in contrast to the cylindrical form most of us are accustomed to. The basic idea is that rather than rolling up the battery innards and placing them in a cylinder, they are stacked like a deck of cards and put into a foil-like pouch. The flat cell is significant for two reasons, energy density—space between the cylinders can consume about 20 percent of the battery pack volume—and surface area that dissipates heat. Moreover, the shape reduces transportation volume, makes assembly easier, and increases the number of cooling options in the automobile.

Before walking around the plant, the conversation turned to company strategy and manufacturing processes. Buck could not contain his enthusiasm for the EnerDel battery and the womb-to-tomb design considerations, not surprising considering he is the director of battery system integration. However, all the EnerDel engineers pride

themselves as one of the few firms, if not the only American firm, that produces an application-specific, fully integrated system of hardware and software that allows a battery to communicate with the vehicle and monitor the performance of each individual cell and the overall pack.

The EnerDel product strategy embraces the entire battery lifecycle: how the batteries will be serviced, replaced, and reused, together with how the cells will be decomposed and their materials recycled. The modular design of the battery pack allows for the quick pinpointing and replacing of troublesome cells. The service technician identifies the sub-pack (containing dozens of cells) that needs to be replaced, disconnects it, pulls it out, and replaces it with a new one. The entire process would take about fifteen minutes. He then sends the toolbox-sized sub-pack back to EnerDel for repair or replacement of the faulty cell.

Eventually, battery performance declines with age. While the aging batteries may lack the C-rate for the automobile acceleration, the ability to hold 80 percent of the originally specified power can be used for stationary applications. For example, the battery can be deployed to store electricity for peak loads on the power grid. In other words, the batteries would provide the smart grid of the future the ability to smooth electricity demand and generation. Large banks of older batteries can store the electricity generated by wind farms for later use. Households can use a smaller bank of a few units—no bigger than a linen closet—to pull from the power grid when electricity is cheaper and discharge when electricity is more expensive.

A Question of Scale

How many of these battery packs can this facility produce? It depends on whether they are EV or HEV units. The present facility, running with two shifts six days a week can produce about 16,000 EV packs a year, double that if they are for HEV applications. The HEVs don't have the power requirements of fully electric. I did some quick math: If Toyota sold about 160,000 units of the Prius in 2008 in the United States, that would mean facilities ten times the size of the EnerDel plants in Indianapolis if EnerDel was the sole source. It boggles the mind to consider scaling up to produce the number of battery pack units to meet the Obama administration's goal of one million fully electric vehicles on the road by 2015. How would an EnerDel, and those firms that supply rather boutique material inputs, fulfill that demand?

Battery production needs a lot of space; the combined square footage of the Indianapolis plants total 127,000. It also requires a lot of sophisticated, fantastically expensive, and highly proprietary capital equipment.

EnerDel is still tweaking the battery chemistry—they have a separate production lab for R&D to keep production models separate from prototypes—but production engineering and high-volume manufacturing appear to be the dominant challenges.

The federal government has stepped in to help address these challenges. EnerDel, along with several other Indiana companies[2] and dozens across the country, was identified to receive federal grants for R&D and to increase manufacturing capacity for manufacturing "green cars." Unlike most federal R&D grants that tend to focus on primary research and science, these funds will enable EnerDel to transition to high-volume production. EnerDel, recipient of the largest grant to a firm in Indiana, gained possession of its $118.5 million grant on March 3, 2010.[3] Even though the company did not have the cash in hand, the firm made plans to spend it. In January, EnerDel announced its investment plan to lease and equip a new manufacturing facility in Hancock County.[4]

I asked Sean Hendrix, director of program management and battery management systems development, if this R&D seed funding for EnerDel and other advanced automobile companies would be sufficient to surmount the threat from Chinese battery manufacturers. He wasn't sure "threat" was the right term[5] but did note that the Chinese government has spent liberally on R&D for green technologies and that they have also spent considerable resources "tooling up the academics" that would train the next generation of green technology engineers and scientists. Like manufacturers in the United States, China has the challenge of taking proven technologies to mass-volume commercialization.

The Manufacturing Process

The building blocks of the batteries, the innards of the cells, are better described as building wafers. The first series of steps combine a thin foil—much thinner than the foil in your kitchen drawer—of either aluminum or copper, with various active materials such as manganese or mixed oxides for cathodes. The mixing room contains something of a vastly scaled up Home Depot paint-mixing machine to prepare the coating for the foil. The chemical slurry looks like thick black paint. This paint is, for want of a better term, "sprayed" onto the copper or aluminum foils—the mechanics of the application is a closely held secret. The foil then goes through a long, tunnel-like drying machine that bakes the paint to the foils.

Following that, the next series of steps turns the specialty-coated foil into battery electrodes. The foil is unspooled and squeezed between two large, precision rollers to ensure that the material on the foil is perfectly flat. (The slightest bump, not even visible to the naked eye, would potentially short the battery when the sheets are stacked.)

Precision machines cut the electrodes into sheets about the size of letterhead stationery, but half as thick as a sheet of paper. From there, the electrodes will be stacked in an ultra-clean, ultra-dry environment.

The next series of steps assemble the electrodes into battery cells. Automated stacking machines pick up an anode, cathode, and a super-thin polymer separator and stack them in a series. The anode/cathode sandwich is then inserted into a metallic, silvery pouch and hermetically sealed on three edges. The last manufacturing step fills the cell with an electrolyte and seals the last side of the cell. The completed cell is about a fourth of an inch thick.

Before assembly into battery packs, the cells are tested. After leaving the assembly room, the cells are charged for the first time in what is called the formation process, and then the cells are aged. Only by aging can the cells be monitored to determine whether they meet all specifications. Once the cells have passed the final quality check, they are ready for assembly into the packs that will power a vehicle. The vehicle battery packs are built from sub-packs built from modules of about a dozen cells.

The flat cells are stacked into modules, and these, in turn, are assembled into sub-packs. Depending on the energy requirement for the vehicle, the final battery casing may consist of a couple of sub-packs or many. Fully electric vehicles require greater C-rates and thus need twice the number of sub-packs as a hybrid. The six sub-pack battery casings for EVs dominated the shop floor when I visited. As the sub-packs are grouped together in the final casing, the electronic hardware and software that monitors cell health and status and integrates the batteries with the power requirements of the vehicle are also installed.

The modular nature of the complete battery package has several advantages for both the manufacturer and consumer. On the manufacturing side, the voltage for the sub-pack is low enough that high-voltage gear isn't needed for the technicians until the last stage of assembly. For the consumer, a sub-pack can be removed and replaced in a couple of minutes should a cell go bad. Moreover, an 80-pound sub-pack is easier to ship back to the plant for diagnostics and repair than a complete, welded battery assembly that can weigh 600 pounds.

> *"If Toyota sold about 160,000 units of the Prius in 2008 in the United States, that would mean facilities ten times the size of the EnerDel plants in Indianapolis if EnerDel was the sole source."*

Once EVs and HEVs have sufficient market penetration, and once EnerDel ramps up production to help meet the million vehicles or more in global annual unit sales, cell production and battery pack assembly can be geographically separated. While I did not discuss this with the EnerDel team, I could foresee a time when the cells would be manufactured in Indiana and then would age en-route to assembly facilities closer to the vehicle assembly and customer.

Who Killed the Electric Car?

Hendrix chuckled at my question and said, "It doesn't matter. What matters is that without that first foray into electric cars in the 1990s, the battery technology would not be as developed today. We have several of the folks who worked on that project. They were the pioneers."

Hendrix then talked about who composed the talent pool from which to draw to expand capacity, namely anyone with battery technology education or experience. "Auto industry experience is best. As a Hoosier, I'd like to hire regionally, but the talent is global." Buck agreed that they need to look globally for engineering talent.

Hendrix also talked about EnerDel's relationship with universities in the state like Purdue, Rose-Hulman, and Indiana University–Purdue University Indianapolis (IUPUI) and how engineering curriculum can be modified for the needs of the transforming industry: "We want these graduates to be ready to work on advanced batteries on their first day."

Whether the designers and engineers of the original electric car, GM's EV1, had the palpable enthusiasm of the team at EnerDel, I don't know. But if they could bottle their zeal, it would power the auto industry for a very long haul.

Notes

1. Most of this article was originally published as "Batteries of a Different Shape" by *Progressive Engineer*, an online magazine covering all disciplines of engineering in the Unites States: www.progressiveengineer.com/features/EnerDel.htm. It is reproduced with permission.
2. While six Indiana businesses (and a group of universities) were awarded grants for electric vehicle battery and component manufacturing in August 2009, they would not actually see the money for some time. According to information on the Department of Energy's Energy Efficiency and Renewable Energy website, awardees of funds for Congressionally Directed Projects must apply for their funds upon being selected to receive them. Remy, Inc. received final approval to use its $60.2 million on May 24, almost ten months after President Obama originally announced the grants in a speech in Elkhart (www.insideindianabusiness.com/newsitem.asp?id=41832).
3. www.wishtv.com/dpp/news/business/enerdel-receives-$18.5m-stimulus-grant-.
4. www.insideindianabusiness.com/newsitem.asp?ID=39737.
5. In late May, EnerDel announced a joint venture with China's largest auto parts producer, enabling EnerDel to break into the Chinese auto market: www.insideindianabusiness.com/newsitem.asp?id=41900.

Census 2010 Participation Rates

Rachel M. Justis: Geodemographic Analyst, Indiana Business Research Center, Kelley School of Business, Indiana University

This summer, Census workers have been in the field, going door-to-door following up on households that did not return their census form by mail (a procedure known to census junkies as non-response follow-up). Given that high mail participation rates are correlated with more accurate data and lower costs, it is good to note that Indiana had one of the highest mail participation rates in the nation and many areas saw improvement relative to Census 2000.[1]

States

Indiana tied with Iowa for third in the nation with a mail participation rate of 78 percent. The national rate was 72 percent, with participation ranging from 62 percent in Alaska to 81 percent in Wisconsin (see **Figure 1**).

Nationally, the 72 percent participation rate showed no change since Census 2000. At the statewide level, Indiana saw a 2 percentage point increase in participation over Census 2000. It was one of twenty-one states to see rates improve compared to the last census. North and South Carolina showed the largest improvements, with rates increasing by 8 percentage points. On the flip side, Wyoming saw a 4 point decline in participation.

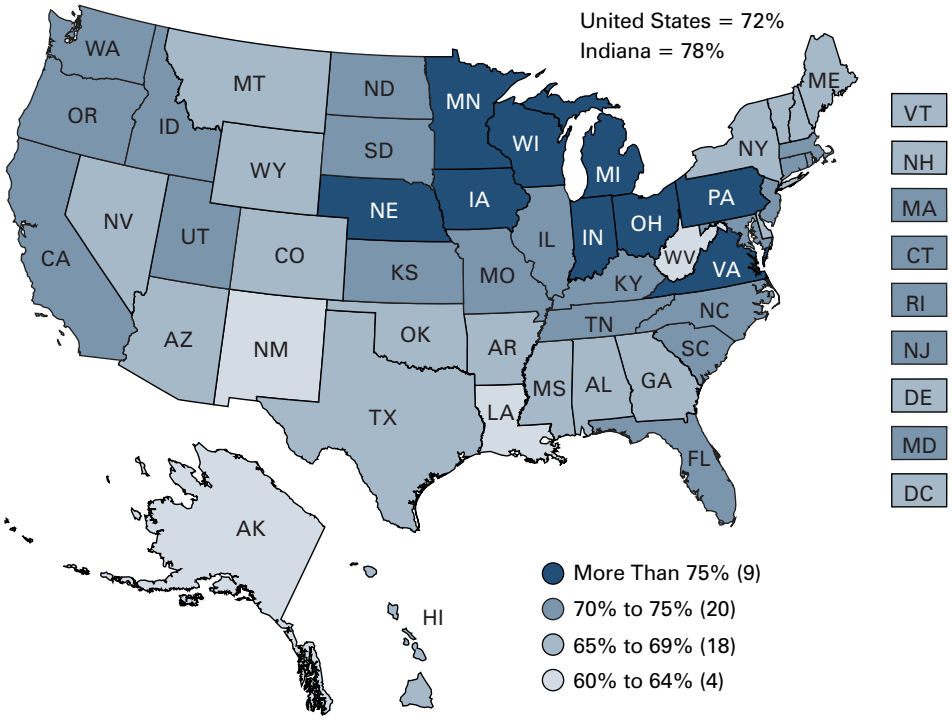
The Census Bureau released rates on a daily basis to allow local officials to track their participation during March and April. **Figure 2** shows that while Indiana had higher rates overall, the basic mail-back trend mirrored the nation.

Counties

Within Indiana counties, participation ranged from 67 percent in Greene County to 86 percent in Dubois County (see **Figure 3**).

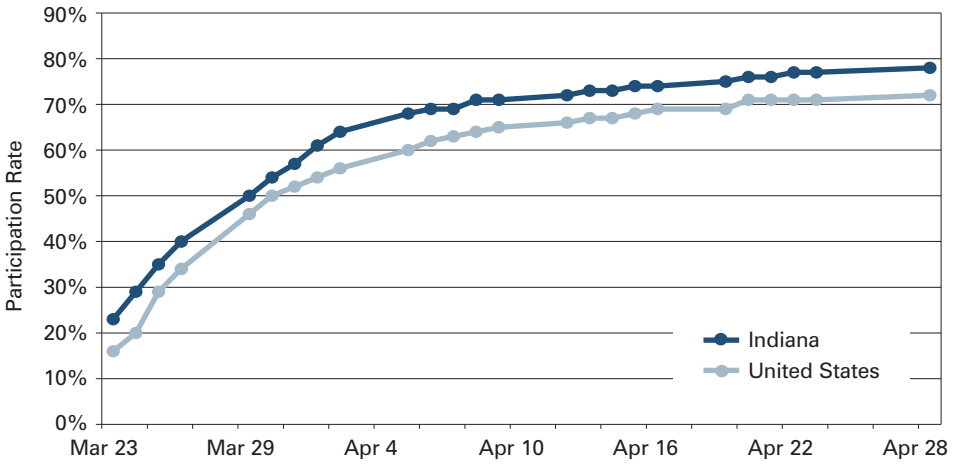
Fifty counties saw increases over Census 2000, led by Crawford County with a 19 percentage point gain (for a 2010 rate of 81 percent). Five counties (Crawford, Owen, Jennings, Pulaski, and Switzerland) saw increases of 10 percentage points or more. White County saw the largest drop in mail participation between the decennials, moving from 77 percent in 2000 to 71 percent in 2010.

Figure 1: Census 2010 Mail Participation Rate by State



Source: IBRC, using U.S. Census Bureau data

Figure 2: Daily Mail Participation Rates, March 23–April 28, 2010



Note: Data were only released Monday through Friday and the Census Bureau did not release data between April 24 and April 28. Hash marks indicate every two days.
Source: IBRC, using U.S. Census Bureau data

Cities and Towns

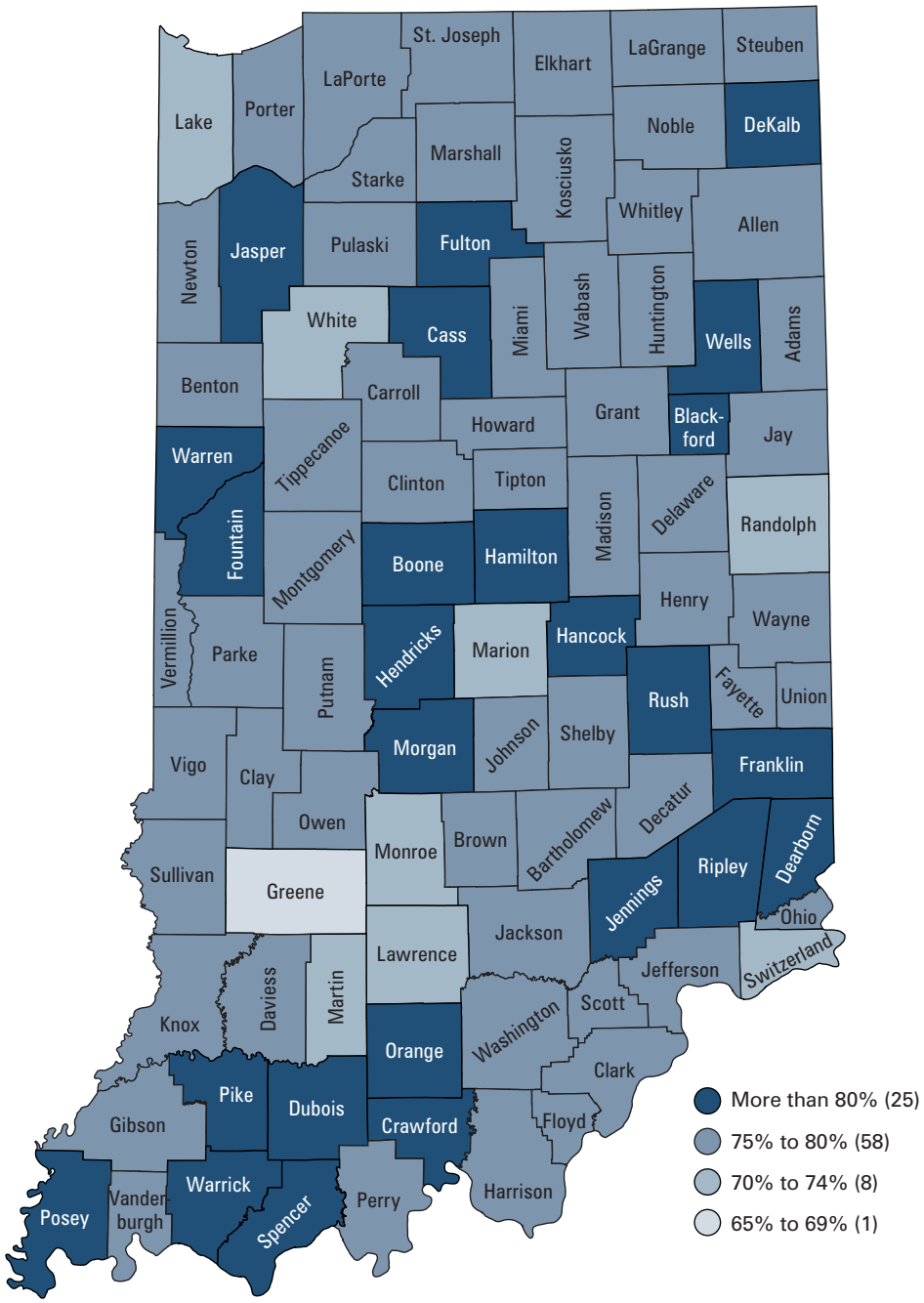
The tiny town of North Crows Nest (population: 44) in Marion County boasted a 100 percent participation rate. At the other end of the spectrum, the town of Macy (population: 228) in Miami County had the lowest rate in the state at 38 percent.[2]

Table 1 focuses on the 20 largest cities and towns in the state, showing Carmel with the highest participation (85 percent) among this group. Compared to 2000, eleven of the twenty areas saw increases in their participation, led by Terre Haute, which picked up 3 percentage points since the last decennial. Among all 566 incorporated places in the state, Indiana saw 289 out of 566 with higher rates compared to Census 2000.

Tracts and Townships

Census tract and township data help us look closer at individual areas since participation can vary significantly within a city or county. Tracts are useful for looking at urban areas, while townships are useful for more rural areas. (Tracts are delineated based on a rough population threshold; therefore, they are significantly smaller than townships in urban areas, but can become quite large in rural areas). Interactive maps

Figure 3: Census 2010 Mail Participation Rate by Indiana County



Source: IBRC, using U.S. Census Bureau data

Table 1: Census 2010 Mail Participation Rate for Indiana's 20 Largest Places

City/Town	2010 Participation Rate	Change from 2000*
Carmel	85%	1%
Fishers	84%	0%
Noblesville	81%	1%
Columbus	78%	0%
Fort Wayne	77%	2%
Lafayette	77%	-1%
Mishawaka	77%	0%
Greenwood	77%	-3%
Kokomo	77%	1%
Terre Haute	76%	3%
Evansville	75%	-3%
Anderson	75%	2%
South Bend	74%	1%
Muncie	74%	2%
Indianapolis	73%	2%
Lawrence	73%	1%
Elkhart	71%	2%
Bloomington	70%	0%
Hammond	68%	-3%
Gary	67%	-2%

*Indicates percentage point change
Source: IBRC, using U.S. Census Bureau data

showing participation rates for both geographies are available on Indiana's Census 2010 website: **www.census.indiana.edu**.

Prior to the census, the Census Bureau developed a hard-to-count score, which assessed how tracts performed on twelve variables correlated with high non-response rates.[3] Scores can range from 0 to 132, with 0 being the easiest to count and 132 being the hardest to count. Tracts with scores above 70 were classified as hard to count. Out of 1,409 tracts statewide, Indiana had 125 classified as hard to count. These were concentrated in urban areas across sixteen counties, but over half (54 percent) of the hard-to-count tracts were in Marion and Lake counties.

Table 2 shows that the average participation rate declined for each grouping on the hard-to-count continuum. The interesting take-away from this table is that the hard-to-count tracts saw a 4 percentage point increase over Census 2000 participation, larger than the change in any other group. This indicates that efforts to target hard-to-count areas were indeed successful.[4]

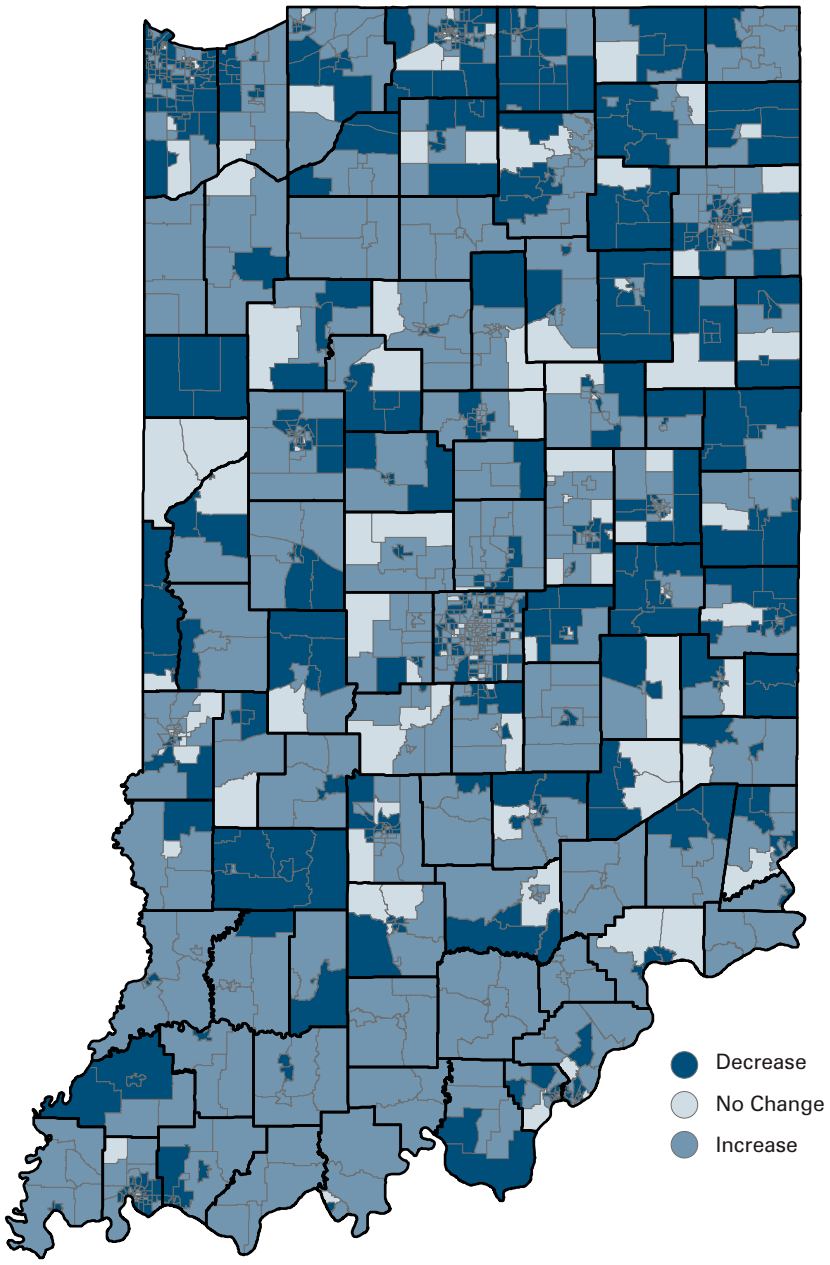
"The interesting take-away from this is that the hard-to-count tracts saw a 4 percentage point increase over Census 2000 participation, larger than the change in any other group. This indicates that efforts to target hard-to-count areas were indeed successful."

TABLE 2: Average Mail Participation Rate by Hard-to-Count Score

Tract Group	Number of Tracts	Average of 2010	Average of 2000
Total	1,409	76%	75%
1 to 10 (Easy to Count)	548	82%	81%
11 to 20	226	77%	77%
21 to 30	160	76%	76%
31 to 40	108	75%	74%
41 to 50	110	73%	72%
51 to 60	60	70%	69%
61 to 70	72	66%	65%
70+ (Hard to Count)	125	63%	59%

Source: IBRC, using U.S. Census Bureau data

FIGURE 4: Percentage Point Change in Participation Rate by Tract, 2000–2010



Source: IBRC, using U.S. Census Bureau data

In fact, while only 48 percent of all tracts improved their performance over Census 2000, 71 percent of hard-to-count tracts saw increases in their participation rates (see **Figure 4**).

Figure 5 plots the hard-to-count score for all of Indiana's tracts against their 2010 participation rate. There is a correlation between high hard-to-count scores and lower participation rates, though one can see that several tracts that were not deemed hard-to-count had relatively low participation rates (i.e., 70 percent or below). Many of these were located in the less urban areas of the state.

Figure 6 shows mail participation rates by township. Rural areas had both some of the highest participation as well as some of the lowest participation. The cluster of low participation in Greene, Martin, and Lawrence counties is notable; this could be due to a variety of factors, such as large numbers of vacant housing in the area, but an exact explanation is unknown.[5] It will be especially important for non-response follow-up to be successful in these areas.

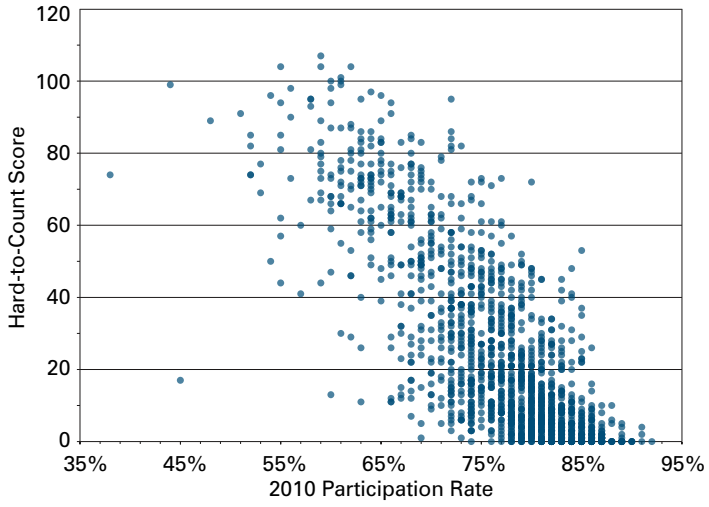
Conclusion

Most Hoosiers did their part and mailed their census forms back before census takers began door-to-door canvassing. This both saved tax dollars and helped ensure Indiana is accurately enumerated. Across the state many areas saw participation rates improve over Census 2000, particularly in many of the traditionally hard-to-count urban areas. As Phase 2 of census data collection wraps up, visit **www.census.indiana.edu** for updated news and information.

Notes

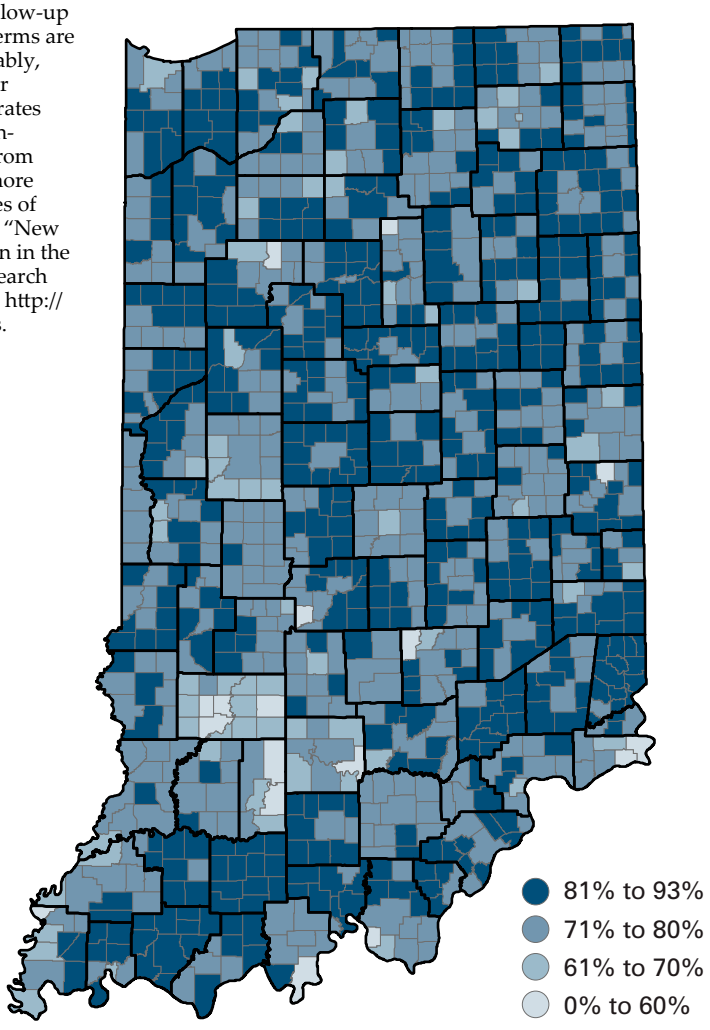
1. The participation rates used in this article are the rates released on April 28 and are the final rates prior to the cut-off for non-response follow-up operations. While the terms are often used interchangeably, participation rates differ slightly from response rates in that they exclude non-deliverable addresses from the denominator. For more information on the types of rates, see D'Vera Cohn, "New Measure of Participation in the 2010 Census," Pew Research Center, March 11, 2010, http://census.pewsocialtrends.org/2010/new-measure-of-participation-in-the-2010-census.
2. Population numbers are the 2008 population estimates produced by the Census Bureau and are given only for reference.
3. Learn more about the hard-to-count scores and view maps at www.census.indiana.edu/ccc/htc.html.
4. For example, the Center for Urban Research at the City University of New York notes that the Census Bureau's replacement mailing strategy was quite effective nationally: www.urbanresearch.org/resources/census2010participationApril28.
5. However, it is not likely due to the Census inappropriately trying to send forms to a physical address when the resident actually receives his or her mail at a P.O. Box because the participation rate omits those addresses where the form was undeliverable.

Figure 5: Relationship between Hard-to-Count Score and 2010 Participation Rate for Tracts



Source: IBRC, using U.S. Census Bureau data

Figure 6: Census 2010 Mail Participation Rates by Indiana Township



Source: IBRC, using U.S. Census Bureau data