



Manufacturing Productivity Through the Great Recession: *What Does It Mean for the Future?*

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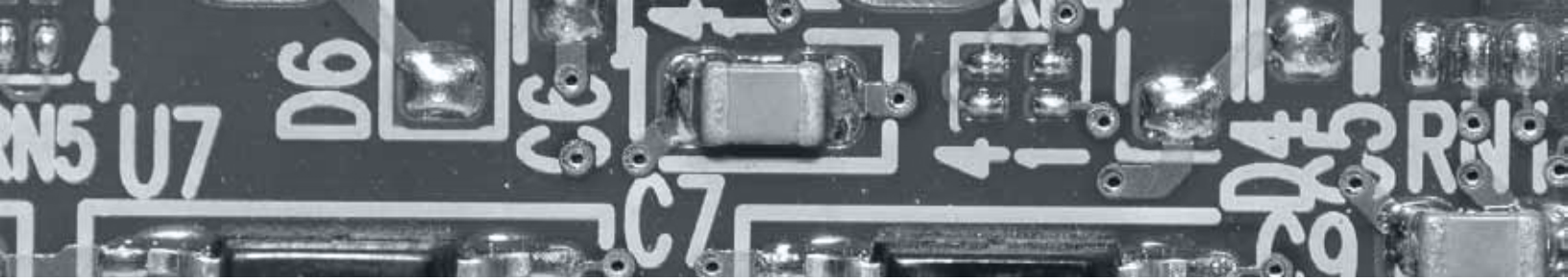
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Executive Summary

This study examines four types of manufacturing productivity growth from 2004 to 2011, with a discussion of the implications for the future of manufacturing in the United States. Firstly, we find that technological improvements have provided a constant source of annual productivity growth in manufacturing throughout this turbulent period. Second, while output per worker has risen dramatically, the overall contribution of labor to manufacturing production growths has been negative as the sector shed jobs from 2004 to 2011. So, manufacturing production rose despite a loss of workers. New capital expenditures (especially in real estate) boosted overall manufacturing production during the pre-recession years, but declined by an average of more than 13 percent during the recession. Since the recession, capital investment has returned to play a large role in manufacturing growth.

Total factor productivity (TFP) is the most significant component of productivity growth because it represents that part of production growth that is not accounted for in our measures of employment numbers, new technology or capital investment. So, TFP may be described as that part of growth that results from effectively organizing production to take advantage of new technology and improved human capital in production. In the pre-recession period, TFP was negative, representing a relatively inefficient combination of capital, labor and technology. This is widely attributed to two factors. Low TFP growth is a by-product of a 'bubble' period, in which firms retained relatively unproductive establishments and workers to meet excessive demand for goods. Low TFP is also attributed to the widespread organizational changes that accompanied a decade long period of IT investment.

As businesses reorganized themselves to take advantage of new information technology in their production process, TFP temporarily waned. During the recession, TFP rebounded as business shed less productive plants and workers. Since the end of the recession, TFP has continued to grow dramatically, accounting for almost half of all production growth. Because rapid TFP growth implies an increasingly advanced production process, it is cause for optimism within the manufacturing sector. It also suggests that demand for new capital and workers will continue to be concentrated within more technically sophisticated production, and in better educated, higher skilled workers. Finally, we report that Indiana leads the Midwest in total factor productivity growth, and ranks 14th nationally in post-recession TFP growth.

Introduction

In the wake of the Great Recession, there has been extensive conversation over the prospects of manufacturing growth in the United States. This study seeks to advance that discussion with analysis of the effect of the Great Recession on manufacturing productivity. This is an important issue for broad policy interests at the state and federal levels. This analysis explores these issues in three parts—First, we explain the sources of manufacturing productivity and estimate changes to productivity over the Great Recession. From there, we explain why this productivity has changed and what it means for the short term and medium term for manufacturing. Finally, we describe how policy can influence the outcomes we describe over the long term.

Manufacturing Productivity

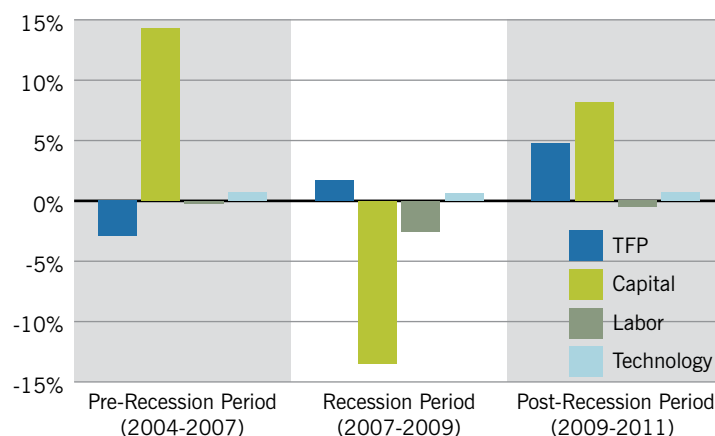
Few issues in economic research have received closer continued scrutiny than productivity growth. In its general form, economists measure productivity as the relationship between an input to the production process, and an output of production. We view the productivity of a firm, industry, or region as a function of available technology, productive land and capital, workers, and a catch-all variable known as ‘total factor productivity’ (TFP), which is simply the growth in production that cannot be explained by changes to technology, capital, or labor force. We begin our examination of productivity with an new analysis of manufacturing, focusing on the lessons from other research that are germane to our initial findings.

To examine productivity in the wake of the Great Recession, we examine data on total manufacturing, by state, from 2004 through 2011 in the United States. This is the most recent manufacturing data available, and is produced from the Annual Survey of Manufactures to which we combine specific capital stock data from the 2002 Economic Census (which is conducted every five years). These data permit us to test several productivity characteristics in Indiana.

Our first finding is that overall productivity of manufacturing in the United States was heavily affected by the Great Recession. Within the overall economy, a number of analysis have identified a slowing of productivity growth from a very high level in the 1990s to static or declining productivity in the mid 2000s (Fernald 2012). Our finding suggests that total factor productivity actually shrank during the observed period of 2004 through 2007. While it is too early to conclusively identify the cause, one very strong argument is that the IT boom preceding it led businesses to undergo a period of “complementary innovations, including business reorganizations.”⁽¹⁾ This might have stalled productivity growth during this transition as businesses reorganized for future profitability.

In 2007, the economy slipped into recession, and, in 2008, a serious economic crisis developed, leading to rapid job losses and a deep and protracted business cycle, which heavily impacted the manufacturing of consumer durables, residential fixed investments, and new plant and equipment. During the recession, overall productivity in the economy boomed, as businesses cut their input growth and the economy shed itself of the least productive firms and workers. In the years following the recession, the aggregate economy saw increases in capital, labor, and TFP growth—none of which have been sufficient to spawn rapid economic growth. However,

Figure 1. Cumulative Impact of Productivity Factors to Manufacturing Growth, 2004–2011



Source: U.S. Department of the Census Annual Survey of Manufacturers.

the effect on manufacturing differs from the economy as a whole. While productivity growth in manufacturing echoes many of these trends, it has not stalled in the years since the recession. To better understand this, we examine three periods—the pre-recession period of our data (2004-2007), the recessionary period (2007-2009) and the post-recessionary period (2009-2011). In each of those periods, we estimate the total contribution of each productive source to overall manufacturing output in each state, over each time period. This is calculated by combining the change in that input in actual value (e.g. capital expenditures or number of employees) and the impact of that overall factor on production.⁽²⁾ The national average of each factor’s contribution is displayed in *Figure 1*.

Some explanation of each of these factors illuminates the anecdotal evidence from the business cycle over the past decade. First, the growth of technology has been positive and fairly constant over the observed period of growth. This is consistent with most existing research on technology transfer.⁽³⁾ The contribution of labor has been consistently negative throughout the observed period. This is due to a combination of a diminished or lessened effect of employment levels on production, and due to an overall lower level of employment in manufacturing during this period. To be clear, the production per worker increased during this period (i.e. each employee produced more goods than he/she did in each previous year), but

1. See Fernald 2012 pg. 1; and Oliner, Sichel, and Stiroh 2007.

2. These are the coefficients on these factors estimated in the production function outlined in the appendix. The overall effect of a common technology and TFP are estimated together. They are not separated since physical inputs of both are not readily countable.

3. See Isaksson 2007.

the actual number of employees declined; so, the overall contribution to growth of manufacturing production was negative.

The contribution of productive capital to overall manufacturing growth is massive. During the pre-recession period, there was a significant increase in capital acquisition. Across both manufacturing and the aggregate economy, this acquisition was led by the purchase of structures (Fernald 2012). This ‘capital deepening’ contributed to some overall contribution to productivity in advance of the recession. The very significant decline in commercial capital acquisitions (e.g. structures and equipment) during the recession resulted in a deep, negative contribution of direct capital to productivity growth during the recession. However, as with the effect of labor on productivity, the capital contribution over the business cycle is a very nuanced issue, because total factor productivity is related to the interactions of both capital and labor on the factory floor.

From the outset of the recession, total factor productivity recovered significantly from its decline in manufacturing during the pre-recession period. This drop in TFP has been confirmed in other studies across the aggregate economy and is attributed to several factors (Fernald 2012). Among the contributions to declining TFP in advance of the recession are the increase in acquisition of relatively unskilled workers during the ‘bubble years’ and the effect of business reorganization following a decade of intensive IT acquisition.

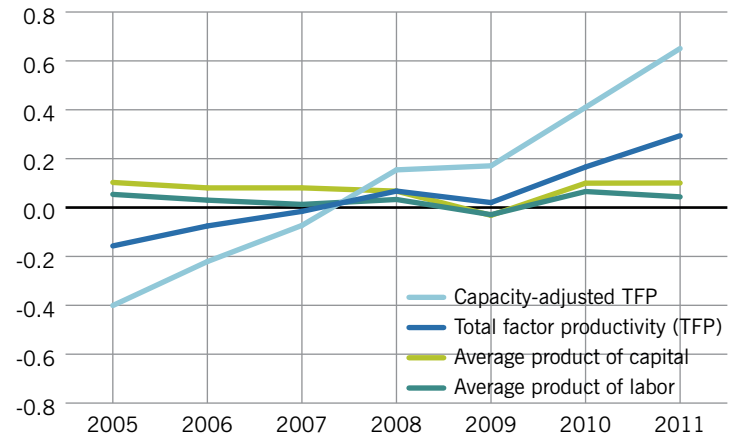
Fortunately, TFP rebounded during the recession and thereafter. A very plausible explanation for manufacturing TFP recovery during the recession is the aforementioned shedding of less productive inputs (both workers and capital). The simple unemployment and closure of unproductive factories would be sufficient to boost TFP during the deep downturn, but this does not explain the persistent growth in TFP following the Great Recession, nor can it explain the fact that manufacturing TFP as reported in this study continued to increase through the most recent data (2011) while TFP in the aggregate economy returned to its pre-recession levels (Fernald 2012).

To better understand the diverging TFP in manufacturing (and its turnaround from the mid 2000s), it is helpful to better understand the dimensions of TFP in the manufacturing sector. Economists can readily measure the expenditures on capital and the number of workers in an economy, and so growth in these two factors of production can be easily explained and included in a growth model. The quality of that capital and labor is a more elusive metric. Ironically, technology, which suffers an equally elusive quality measure, diffuses quickly across economic sectors and regions. As a consequence, the impact of technological growth alone can be captured in a traditional statistical model as a common impact.⁽⁴⁾

Total factor productivity reflects the unobserved interactions between capital, technology, and workers. As such, TFP growth serves as an implicit metric of the efficiency with which businesses combine their individual workers, available technology, and capital into the manufacture of goods. This metric then captures improving labor quality and capital quality as they are deployed in tandem.

Total factor productivity growth is far more scrutinized because it represents the accumulated benefit of human knowledge and invention, which is why it is sometimes referred to as ‘disembodied’ economic growth. It is beyond the scope of this paper to fully explain the factors that contribute to TFP differences across time and regions. However, a very detailed review of three decades of empirical studies suggests that for a developed nation,

Figure 2. Changes in TFP, Capacity-Adjusted TFP, Average Product of Capital, and Average Product of Labor in Manufacturing, 2004–2011



Source: U.S. Department of the Census Annual Survey of Manufacturers; and author’s calculations.

Rapid TFP growth implies an increasingly advanced or sophisticated production process within manufacturing. At the plant level, this growth likely leads to declining demand for workers. However, at the aggregate level, high levels of TFP attract business investment, which in turn may fuel employment growth.

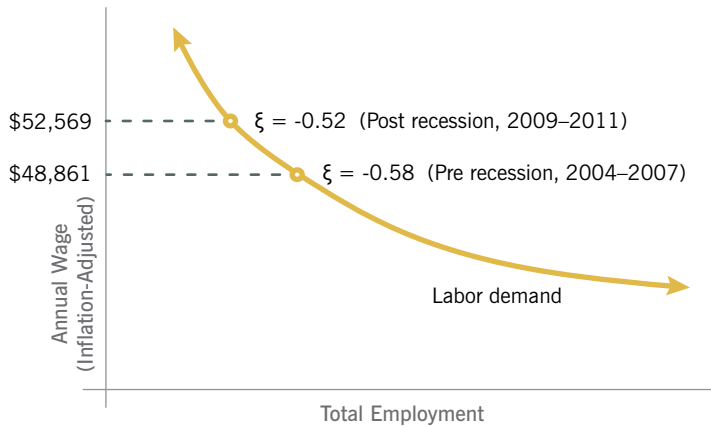
factors such as education and infrastructure play a dominant role. We will discuss this more when we make cross-state comparisons and more fully discuss public policy. However, the estimation of TFP across a business cycle suffers from at least one weakness, which is the overall ‘slackness’ in labor and capital utilization that accompanies a recession.

Earlier work (Fernald 2012; Fernald and Matoba 2009) discuss a capacity utilization adjustment for estimates of TFP. We do so here, confining the technical details to the appendix. We find that when we control for the drop in factory capacity use during the recession (and subsequent rebound) that total factor productivity growth is much larger than that depicted in *Figure 1*. Indeed, with these calculations, the growth in TFP swamps the capital growth’s contribution to expanding manufacturing production in the post-recessionary period. See *Figure 2*.

From our national analysis of productivity within the manufacturing sector, we clearly find that a rebound from the pre-recessionary period of declining total factor productivity, manufacturing has rebounded to a dramatic level of productivity growth. The implications for this are nuanced. Rapid TFP growth implies an increasingly advanced or sophisticated production process within manufacturing. At the plant level, this type of productivity growth likely leads to declining demand for workers. However, at the aggregate level, high levels of TFP attract business investment, which in turn may fuel employment growth.

4. The intercept in a time varying growth model is then interpreted as a constant technology parameter across all regions.

Figure 3. Demand for Manufacturing Labor in Pre-Recessionary and Post-Recessionary Periods



Note: Elasticity values are statistically different at the 10% level in a Wald Test.
 Source: U.S. Department of the Census Annual Survey of Manufacturers; and author's calculations using a labor demand model.

To evaluate this, we test the demand for manufacturing labor in the pre-recessionary and post-recessionary periods. We find that the demand for labor has become less responsive to wages (less elastic). This is consistent with a finding that the labor component of manufacturing is relatively more important to the production process through its contribution to total factor productivity. *Figure 3* displays the inflation-adjusted annual salary in 2007 and 2011 and the estimated demand elasticities for workers over the 2004-2007 and 2009-2011 periods.

The consequence of this for manufacturing is that the overall industry demand for manufacturing workers is less responsive to labor costs than in the pre-recession period. This has accompanied real wage growth for manufacturing workers. Both of these outcomes are wholly consistent with the observed growth in total factor productivity derived from labor inputs.

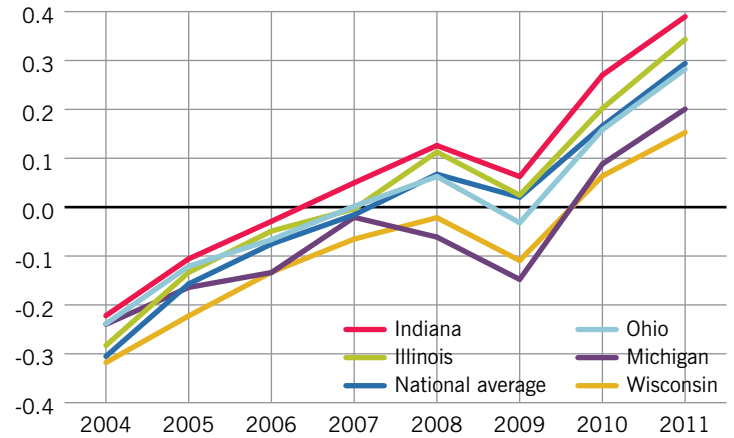
Regional Differences in Productivity

Differences in TFP growth across regions are of interest for many reasons. First, firms will implicitly assess the benefit of greater productivity per unit of output accommodated by TFP. Indeed, this is one of the major findings in economic development research over the past half century. Because TFP is dependent upon capital deepening and labor quality, it is sensitive to underlying regional differences in fiscal structure, human capital, and agglomeration economies. Also, to the degree that regions enjoy different mixes of manufacturing firms, relative productivity will vary. So, difference in TFP growth may reflect the accumulated impact of tax policies, educational investment, and other productivity enhancing policies.

To evaluate this, we examine state-level TFP growth over the business cycle, and compare Indiana to the nation as a whole and to other Midwest states with which we share a similar industrial mix in manufacturing. We report this estimate in *Figure 4*.

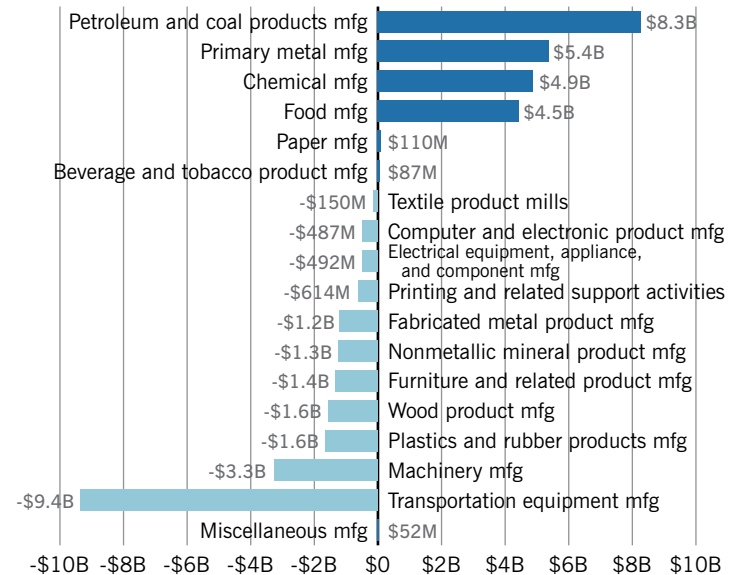
It is clear from this figure that productivity levels in Indiana have exceeded both the U.S. average and the regional averages in surrounding Midwestern manufacturing states. Why this might be is far outside the scope of this study; however, differences in TFP levels may be explained by differences in industrial structures (industry mix). This is why we focus on

Figure 4. Total Factor Productivity in the U.S. and Midwest Manufacturing States, 2004–2011



Source: U.S. Department of the Census Annual Survey of Manufacturers.

Figure 5. Change in Manufacturing Production by Sector in Indiana, 2005–2011



Note: Figures in 2012 inflation-adjusted dollars.

Source: U.S. Department of the Census Annual Survey of Manufacturers.

these states, where the mix of production is so similar. Nationally, Indiana's TFP level ranked 16th in 2011, and 14th in post-recession growth.

Figure 5 illustrates the change in manufacturing production across a more disaggregated view of the leading industries in the state. As is clear from this graph, production grew in food manufacturing, petroleum and coal products, chemicals, and primary metal manufacturing. Production declines were concentrated in transportation equipment and machinery. Overall, manufacturing output grew by \$1.8 billion from 2005 to 2011. While we do not yet have more recent data for production, evidence strongly suggests that growth has continued, and it is likely that overall transportation and equipment production has risen to near its 2005 level.

Summary and Conclusions

This brief analysis outlines the effect of the business cycle on manufacturing productivity in the United States, with a focus on Indiana and the Midwest. These findings demand some interpretation; we discuss four separate forms of productivity: technology, capital, labor, and total factor productivity (TFP).

Technological growth and diffusion continues to provide a constant, and economy wide boost to overall production. This was largely unaffected by the Great Recession. Capital also, has provided a constant and high level of productivity, but a significant decline in the acquisition of capital during the recession contributed significantly to the economic slowdown. Both of these findings are generally consistent with research about technology and capital during business cycles.

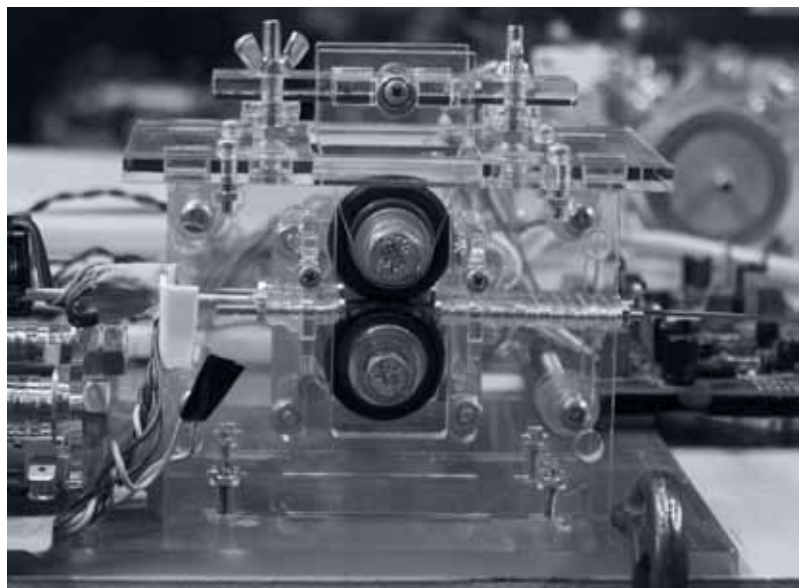
We find that labor productivity has grown also, but for manufacturing, the shrinking labor force means that overall, the impact of those labor-specific productivity gains have been negative since 2004. This is not a trend that has manifested itself economy-wide.

Total factor productivity, that is, the growth in output that is not explained by specific inputs, stalled in the years prior to the Great Recession. In our study of manufacturing, and in economy-wide studies, total TFP shrank in the mid 2000s. The most probable reasons for this are significant business reorganization, which occurred in the wake of heavy IT investments from the mid 1990s until after the 2001-2002 recession, as well as the accumulation of less productive inputs during the bubble years. This latter effect may be interpreted as businesses retaining workers and facilities that were relatively unproductive during these years.

TFP rebounded from the beginning of the recession through the most recent available manufacturing data (2011). Moreover, when we account for low levels of capacity utilization which accompanied the recession and years immediately following, TFP actually grew far more rapidly across the nation's manufacturing sectors.

The most likely cause for this rapid growth in TFP during and after the Great Recession is a surge in the effectiveness with which businesses combined their inputs (labor and capital) and technology in the production of goods. For manufacturing, this suggests that either individual establishments have experienced a dramatic improvement in overall efficiency, or that overall, the production mix in the United States has shifted to the production of goods that enjoy a more productive manufacturing process.

To better understand the dimension of TFP in this analysis, an example should be of use. In the model we have discussed in this study, labor inputs and total factor productivity relate to each other in the nature of the work itself. Suppose there is one very unskilled, labor intensive production process (e.g. a 1950s assembly plant). In this production process, the output levels will be very sensitive to the number of workers employed in a factory, not by differences in the organization of the factories or the skills of individual workers. So, the labor input variable (in the models presented above) will matter greatly, and total factor productivity will not. In contrast, envision the production at a highly skilled manufacturing facility that is OEM for the aerospace or medical device fields. In this factory, a great deal of importance lies in the skills and training of individual workers and the overall organization of the factory. Adding 25 percent more workers to the labor force is unlikely to make material differences in production, while



improving individual skills by 25 percent would. In this case, the labor input variable we report in this paper would matter little, while total factor productivity would matter greatly.

The findings we report on the manufacturing economy in this study appears like a rapid and dramatic shift from the more labor-intensive manufacturing process to the more human capital-intensive manufacturing process. Anecdotal evidence that the U.S. is experiencing a manufacturing renaissance and that manufacturing production is becoming more sophisticated or advanced is entirely consistent with the empirical analysis of manufacturing from 2004-2011. Moreover, there appears no slowing of manufacturing TFP as reported economy-wide in the post-recession period (Fernald 2012).

Of course, some of the rapid shift apparent to anecdotal observation is colored by the deep effects of the recession. In the years leading up to the Great Recession, factories had doubtless maintained unproductive facilities and less productive workers due to a bubble affecting not only real estate assets but also the demand for consumer durables fueled by the artificial wealth held in homes. The Great Recession led businesses to rapidly shed a significant share of low productivity facilities and workers. The transition to more advanced manufacturing appears to have happened very quickly due to this phenomenon, when in fact it has some genesis in the economy-wide adoption of information technology in the previous decades. Nevertheless, the growth in TFP since the beginning of the Great Recession has been significant, and nowhere is that more apparent than in Indiana. TFP growth in the Hoosier state tops the Midwest throughout the sample period. This growth has its genesis in factors related to both public policy and commercial success, for which a full account is outside the scope of this study. However, because Indiana has seen the second fastest post-recession manufacturing recovery, we are confident that productivity growth and overall production growth are closely linked.

Sources and Credits

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About the Author

Michael J. Hicks, Ph.D. is the director of the Center for Business and Economic Research and professor of economics in the Miller College of Business at Ball State University. He came to Ball State following stints at the Air Force Institute of Technology's Graduate School of Engineering and Management and research centers at Marshall University and the University of Tennessee.

Hicks' research has focused on issues affecting local and state economics. His work on the effects of federal regulation of energy and mining industries has resulted in testimony in state and federal courts and the U.S. Senate. His research has been highlighted in such outlets as the *Wall Street Journal*, *New York Times*, and *Washington Post*. He has appeared nationally on CSPAN, MSNBC, NPR, and Fox Business News. His weekly column on economics and current events is distributed through newspapers including the *Indianapolis Business Journal*, the *South Bend Tribune*, and *The Star Press*.

Hicks is a retired infantry lieutenant colonel in the U.S. Army Reserves, having served in combat and peacekeeping operations in North Africa, Southwest Asia, Korea and Japan.

Appendix

Our Cobb-Douglas production function posits output (Y) as a function of technology (A), capital stock (K), labor (N) and total factor productivity (γ), all of which are a function of time. It takes the traditional form:

$$Y(t) = A(t) K(t)^\alpha N(t)^\beta \gamma$$

Which in logarithmic form (dropping time notation):

$$\log(Y) = \log(A) + \alpha \log(K) + \beta \log(N) + \log(\gamma)$$

Where the first derivative of Y w.r.t. A , K , N and γ may be interpreted as the marginal product of each factor, where $\alpha + \beta$ permit econometric testing for scale economies and elasticities of output are interpreted to vary from long run equilibrium, so do not translate into factor price shares in short run equations. The econometric testing is performed using traditional weighted least squares, with a number of minor econometric considerations which are available from the author.

The capacity utilization correction is obtained from a two-stage identification strategy where $Y(t)$ is conditioned on $C(t)$, which is written:

$$\log(Y) + e(t) = C(t) = \log(\hat{Y})$$

$$\log(\hat{Y}) = \log(A) + \alpha \log(K) + \beta \log(N) + \log(\gamma)$$

Labor demand is estimated as:

$$N/K = C(W/R)\epsilon$$

Where the capital labor ratio is a time function of a constant, the wage/interest ratio and an error term, which is estimated in log-log specification, with the F.O.C. yielding a labor demand coefficient on the W/R ratio.

Data are from the U.S. Department of the Census Annual Survey of Manufacturers from 2004-2011 at the state level. Value of shipments is output Y ; number of employees is N , and capital expenditures consists of the 2002 Census of Manufacturers capital stock values, depreciated over the full period, with 2004-2012 change values coming from actual ASM-reported values. Summary statistics appear in *Table A1*.

Table A1: Summary Statistics

	Value of Shipments (\$)	Number of Employees	Capital Expenditures (\$)	Value Added (\$)
Mean	102,000,000,000	251,765	2,884,433	45,312,308
Median	75,053,127,000	177,486	2,143,272	34,963,217
Maximum	671,000,000,000	1,448,485	18,504,794	254,000,000
Minimum	182,212,000	977	5,585	103,907
Std.Dev.	110,000,000,000	249,326	3,089,931	46,347,240

Source: U.S. Department of the Census Annual Survey of Manufacturers, state-level data.

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Conexus Indiana is a private sector-led initiative focused on the advanced manufacturing and logistics sectors—two industries that combined employ more than one of every five Hoosiers. Conexus Indiana is focused on making Indiana a global manufacturing and logistics leader by strengthening the state's human capital, by building industry partnerships to capitalize on new opportunities and address key challenges, and by promoting a better understanding of the importance of these industries to our economic future.

Conexus Indiana's most urgent mission is building tomorrow's manufacturing and logistics workforce, preparing Hoosiers to take advantage of high-tech careers in these exciting fields. Conexus Indiana is also focused on developing a unified strategy to enhance our logistics capabilities, linking manufacturers with in-state suppliers to streamline supply chains and spur investment in Indiana, and undertaking other strategic projects that will help the manufacturing and logistics sectors thrive here at the Crossroads of America.



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