Monthly Labor Review

January 2018

Measuring productivity growth in construction

This article introduces new measures of productivity growth for four industries in construction: single-family residential construction; multifamily residential construction; highways, roads, and bridges construction; and industrial construction. Although previous studies found that productivity is stagnant or declining in the overall construction sector, we find that productivity growth is positive and relatively strong in three of the four industries. The present evidence is more reliable because the output price deflators are more accurate in the four industries considered. This article explains in detail how the new measures were prepared and briefly describes ongoing research that the U.S. Bureau of Labor Statistics is conducting to determine what further measures of productivity growth in construction are feasible.

Leo Sveikauskas
sveikauskas.leo@bls.gov

Leo Sveikauskas is a research economist in the Office of Productivity and Technology, U.S. Bureau of Labor Statistics.

Samuel Rowe
rowe.samuel.t@dol.gov

Samuel Rowe, formerly an economist in the Office of Productivity and Technology, U.S. Bureau of Labor Statistics, is a statistician in the Office of the Assistant Secretary for Policy, U.S. Department of Labor.

James D. Mildenberger
mildenberger.jim@bls.gov

James D. Mildenberger is a supervisory economist in the Office of Productivity and Technology, U.S. Bureau of Labor Statistics.

Jennifer Price
price.jennifer@bls.gov

This article introduces new measures of productivity growth for four industries in construction: single-family residential construction; multifamily residential construction; highways, roads, and bridges construction; and industrial construction. Our overall results show that productivity growth has been positive and somewhat strong in three of the four industries. The industry of highways and associated construction is the exception. These results contrast with previous work,[1] which suggested that productivity growth has been negative or zero within total construction.

These differences in findings are not due to simple data revisions. Our measures instead reflect an analytical advance: we examine only those industries in which the deflators exactly match the industry boundaries. Previous work generally looked at the total construction sector. Since the many new deflators now available did not exist then, these prior studies had to use the single-family housing deflator and an associated cost index to deflate production in most or all of construction.[2]

Jennifer Price is an economist in the Office of Productivity and Technology, U.S. Bureau of Labor Statistics.

Arthur Young
a73bluejay@aol.com

Arthur Young, now retired, was formerly an economist in the Office of Productivity and Technology, U.S. Bureau of Labor Statistics.

The community engaged in construction has often requested that the U.S. Bureau of Labor Statistics (BLS, the Bureau) publish estimates of productivity growth in construction. For example, the white-collar Building Futures Council emphasized in a white paper, “The objective of this white paper is to encourage the Bureau of Labor Statistics (BLS) to continue its initial efforts and introduce and establish improved construction productivity metrics so that productivity changes throughout the construction industry are properly reported and appropriately measured.”[3]

The BLS productivity program has not previously published official measures of productivity growth in construction. The main difficulty is that buildings differ widely in their characteristics and features. Similarly, the nature of the underlying terrain varies widely among construction projects. Consequently, economists, both in general and within the BLS productivity program, have found it exceptionally difficult to develop reliable output price deflators to convert observed revenues into meaningful measures of output growth over time. Good output price deflators are therefore the key to more accurate measures of productivity growth in construction. This article uses four high-quality deflators, each drawn from a different government database.

The BLS Producer Price Index (PPI) program recently released improved measures of output prices for several construction industries. These improved deflators make expanding coverage in the construction sector possible.[4] For reasons explained in the section titled “Measuring productivity growth in additional portions of construction,” we use only one of the new PPI deflators. Nevertheless, the availability of many PPI deflators opens important new possibilities in the study of construction productivity. The Bureau’s productivity program is currently conducting research to determine what further measures of productivity growth are feasible.

Other issues also make measuring and understanding production in construction difficult. For example, information on capital inputs in construction industries is quite limited. In addition, the input–output tables from the Bureau of Economic Analysis (BEA) report materials requirements for final projects rather than for industries. Because of the problems in measuring capital and materials inputs, this article examines only the growth of gross-output-based labor productivity.

The first section describes in detail how we prepared the new measures of labor productivity growth. The second section presents and discusses each of the four new measures. The third section outlines exploratory BLS research intended to determine what further measures of construction productivity are now possible.[5] Throughout this article, labor hours always include partners and proprietors (P&Ps), who account for almost 20 percent of labor input in construction.

Measuring industry productivity growth

This section describes the main data sources used to develop measures of productivity growth for each of the four industries considered.[6] The primary source of data on output and employment used in the new measures is the Census of Construction (COC),[7] which offers the only consistent information on these series. However, we supplement the COC data with data from external sources. This section on measurement describes the steps necessary to generate annual estimates of productivity growth. This article's appendix discusses in more detail how the annual data are benchmarked to the data for census years.

The single-family and multifamily construction data presented do not exactly correspond to standard North American Industry Classification System (NAICS) industries.[8] Our measure of single-family homes includes new single-family housing construction (NAICS 236115), and similarly, our measure of multifamily homes includes new multifamily construction (NAICS 236116). In addition, each of these two measures also contains a portion of the new housing for-sale builders industry (NAICS 236117), which also produces both single-family and multifamily homes.[9] Specifically, we assign the output and employment of for-sale builders to single-family or multifamily construction on the basis of bridge tables published in the 2002 COC, as documented in BLS Working Paper 478 by Sveikauskas, et al. (henceforth called "SRMPY 2014").[10] The two other industries presented match standard NAICS industries: highway, street, and bridge construction (henceforth, highways), NAICS 237310; and industrial building construction (henceforth, industrial construction), NAICS 236210.[11]

Output and deflators

For our output measures, we used deflated revenues from the COC. As noted previously, we restrict our analysis to the four industries for which high-quality deflators are available. First, we developed estimates of output in census years. The main measure of output is the value of business done, as reported in the COC. This article measures, as is standard, industry output as production in all establishments classified in the industry,[12] which includes both primary and secondary products.[13] The value of business done includes revenues from both construction and nonconstruction activities.[14]

Because the COC is conducted only every 5 years, output must be interpolated between census years. To do this, we use a different U.S. Census Bureau report on construction, the "Value of Construction Put in Place," which provides the best annual information on construction output.[15] We use the series for new single-family and new multifamily construction to interpolate annual output growth between census years for these two industries. Similarly, we use the corresponding series on the output of highway and street construction to interpolate between census years for highways construction and the data on manufacturing construction to interpolate between census years for industrial construction.

The availability of each deflator determines the period over which each industry can be studied: we examine single-family and multifamily housing from 1987 to 2016,[16] highways from 2002 to 2016,[17] and industrial construction from 2006 to 2016. The four deflators come from four different sources. First, the U.S. Census Bureau publishes output price deflators for single-family residential construction, using a modified version of the deflator originally introduced in a 1969 article by John Musgrave.[18] This deflator adjusts for the characteristics of houses, such as square footage, the number of bathrooms, or the presence of a garage.[19] A house with more square feet therefore represents more house and more output. The quality of a house is measured only through these characteristics and does not reflect the quality of the workmanship or the number of defects in the completed building.[20] Second, the BEA publishes a similar deflator for multifamily housing. The multifamily residential deflator, originally developed by Frank de Leeuw,[21] likewise allows for improvements in the characteristics of new apartments, condominiums, townhouses, or other multifamily units.[22]

The third deflator is the Federal Highway Administration (FHWA) National Highway Construction Cost Index (NHCCI).[23] Although the deflator is a cost index, the webpage from the FHWA specifically states that their index is intended ". . . to convert current dollar expenditures on highway construction to real or constant dollar expenditures."[24] The FHWA uses the Consumer Price Index to deflate maintenance and repair in the highways industry; however, as explained in SRMPY 2014, we use the NHCCI deflator to deflate maintenance and repair within highways.[25] The fourth deflator, for industrial construction, is from the PPI program.[26] The PPI indexes control for quality by following the cost of the same building over time. Observed price increases are therefore a pure price effect separate from any quality improvement.

SRMPY 2014 describes how output price deflators are selected for the secondary products observed within each industry.[27] Once all relevant information on the output and price of each product has been collected, we calculate a Törnqvist index of output covering all primary or secondary products produced within each industry.[28] This Törnqvist index is the measure of output in each industry.

Labor input

Ideally, the data on inputs and output would come from the same source. Some estimates of productivity growth in construction, as shown in an article by Rojas and Aramveekul, for example, have run into difficulties because the labor-input and output data were collected from different sources.[29] Unfortunately, the COC does not contain information on some aspects of labor input, such as weekly hours of white-collar workers. However, we rely on input data from the COC as much as possible.

The COC collects information on the employment of both construction workers (workers in the various construction trades) and other employees such as professional or clerical workers. To estimate total hours, we need information on average weekly hours as well as employment. The COC provides quarterly data on total hours that construction workers worked, which can be used with employment data in determining average weekly hours. However, the COC contains no information on the hours of nonconstruction workers.

We use data from the BLS Current Employment Statistics (CES) survey to fill in the data that are missing from the COC. First, we use CES data to interpolate employment between census years. For average weekly hours, we use CES data for all years—including census years—because the data contain information on hours for both construction and nonconstruction workers. Since March 2006, the CES has reported the average weekly hours of construction workers and of all employees. Before 2006, the CES collected hours data only for construction workers. SRMPY 2014 describes how we use the CES data to estimate average weekly hours and total annual hours, including for years before 2007.[30] We convert the CES hours to hours worked using an hours-worked-to-hours-paid ratio from the National Compensation Survey. This ratio accounts for vacation time accrued and sick leave taken (though not off-the-clock work).

The COC also collects information on the number of P&Ps, who account for a considerable portion of labor input in many construction industries.[31] Most of the labor hours of P&Ps occur in establishments classified as without payroll, such as a self-employed plumber who hires no additional labor. See the appendix for more information on how self-employed hours are calculated.[32]

Unit labor costs

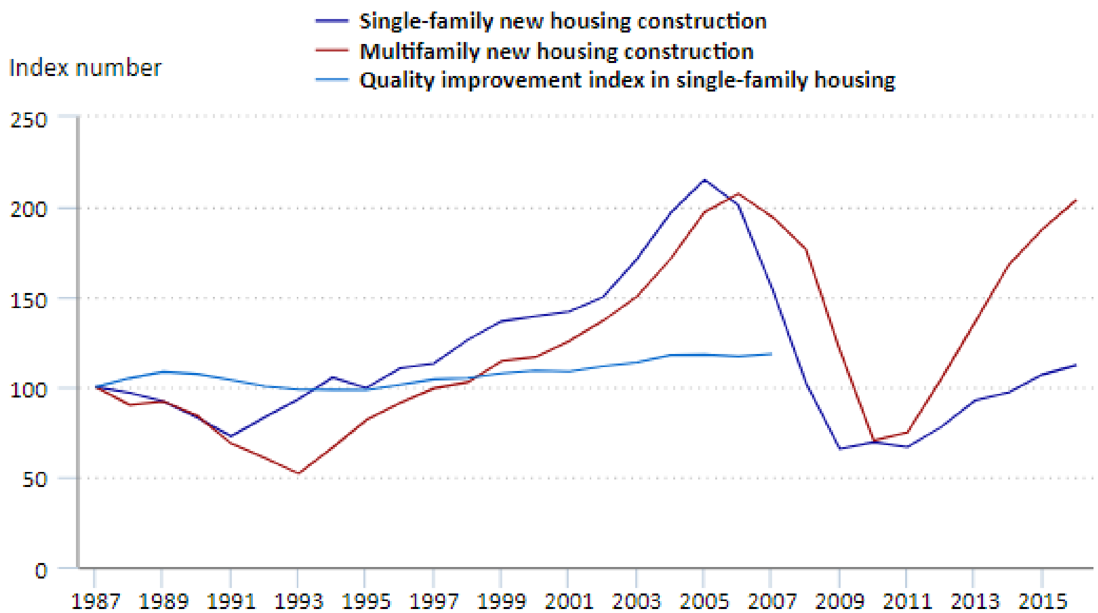
In addition to the fundamental series on output and labor hours, BLS publications on industry productivity growth typically include information on the unit labor costs in each industry. Unit labor costs are defined as total labor compensation per unit of output. In census years, total labor compensation is calculated as the sum of payroll plus employer's cost for fringe benefits from the COC. Between census years, labor compensation is benchmarked to payroll data in each industry from the BLS Quarterly Census of Employment and Wages.

Since no reliable information exists on the labor earnings of the self-employed, self-employed workers are assumed to have the same hourly compensation as employees. The total compensation of employees is therefore multiplied by the ratio of total hours worked to the total hours of employees. Once the authors determine the total labor compensation of all workers, we calculate unit labor costs by dividing total compensation by output.[33]

Productivity growth in four industries

Figure 1 shows output growth in single-family and multifamily new residential construction from 1987 to 2016. Output growth was moderate until the early 2000s but reached a sharp peak during the 2004–07 boom. Multifamily construction reached its peak a little later, presumably because those projects last longer.[34] Most of the output gains observed during the boom reflect a larger number of housing starts. The quality of new single-family homes, as measured by improvements in their characteristics, increased only moderately. After the boom, new housing construction declined sharply in both industries. From 2009 to 2011, housing construction remained in a trough before beginning to recover. Multifamily housing recovered especially rapidly, but single-family residential construction also rebounded substantially.

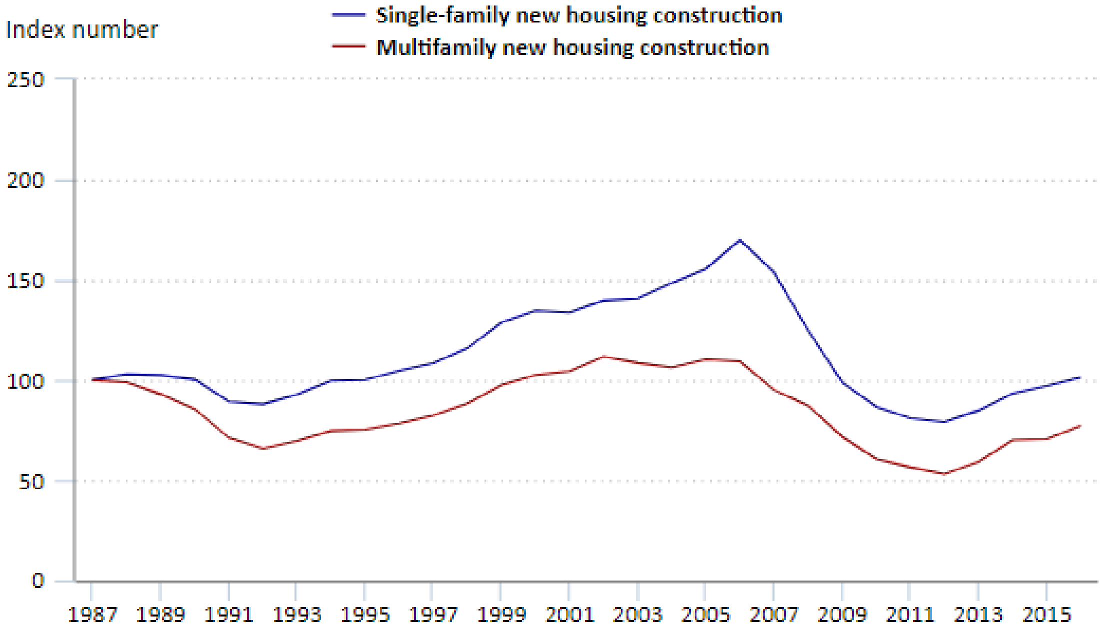
Figure 1. Index of output in single-family and multifamily new housing construction, 1987–2016 (base year 1987 = 100)



Click legend items to change data display. Hover over chart to view data.
Note: Recession periods are July 1990 to March 1991, March 2001 to November 2001, and December 2007 to June 2009, as determined by the National Bureau of Economic Research.
Source: U.S. Bureau of Labor Statistics.

Figure 2 illustrates the corresponding hours in the two housing industries.[35] Over the 1987−2016 period, hours increased much more slowly in multifamily housing. Hours also increased considerably during the boom, especially in single-family housing. During the 2007−09 crash, labor hours, like output, declined sharply in both industries.

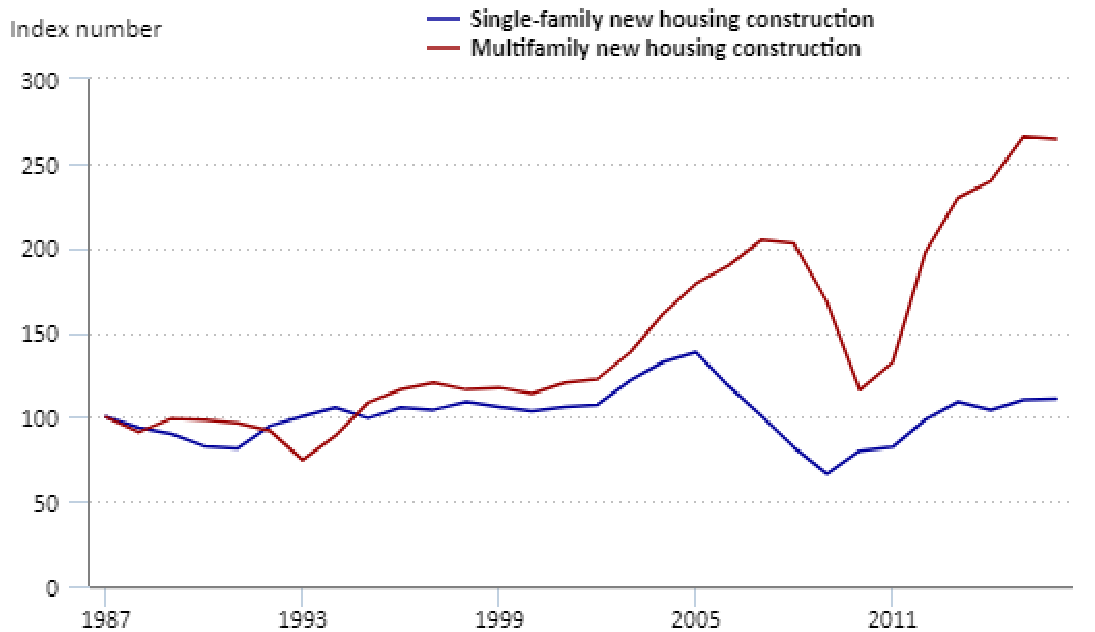
Figure 2. Index of labor hours in single-family and multifamily new housing construction, 1987–2016 (base year 1987 = 100)



Click legend items to change data display. Hover over chart to view data.
Note: Recession periods are July 1990 to March 1991, March 2001 to November 2001, and December 2007 to June 2009, as determined by the National Bureau of Economic Research.
Source: U.S. Bureau of Labor Statistics.

Figure 3 shows the productivity trends that emerge from the output and hours data. Over the entire period, productivity grew more rapidly in multifamily housing, as the slower hours growth observed in figure 2 might imply. Productivity in both segments of housing declined sharply after the boom but recovered strongly in recent years, particularly in multifamily housing.[36]

Figure 3. Index of productivity (output per hour) in single-family and multifamily new housing construction, 1987–2016 (base year 1987 = 100)



Click legend items to change data display. Hover over chart to view data.
Note: Recession periods are July 1990 to March 1991, March 2001 to November 2001, and December 2007 to June 2009, as determined by the National Bureau of Economic Research.
Source: U.S. Bureau of Labor Statistics.

Reporting industry productivity growth using the average annual rate of productivity growth between the first and last years of the data is common practice. However, figures 1 and 3 indicate that the housing industries have been exceptionally volatile in recent years during the housing boom, crash, and recovery. Because of this unusually high volatility, we use an alternative measure of productivity growth that is less affected by the endpoints chosen.

We instead measure long-run productivity growth through a regression framework that estimates the annual rate of productivity growth that best fits the pattern described in figure 3. Labor productivity is equal to O/L , where O is output and L is hours worked. Formally,

$$\log(O/L) = a + b\,t\,, \tag{1}$$

where t is time, measured in years. The dependent variable, $\log(O/L)$, is measured in logarithmic terms, so that the coefficient b shows the percentage change in O/L associated with a 1-year increase in time over the sample period.

As just noted, labor productivity in construction is very cyclical. Controlling for this cyclicality is important because otherwise it could distort long-run trends. The equation then becomes

$$\log(O/L) = a\text{¢} + \gamma\text{¢}\,\log(hs) + b\text{¢}\,t\,. \tag{2}$$

The coefficient b¢ provides an estimate of long-term productivity growth, adjusted for the number of housing starts (hs), and γ¢ shows the percentage increase in productivity associated with each percentage-point increase in housing starts. Single-family housing starts are used in the single-family equation, and multifamily housing starts are used in that equation. By allowing for cyclical effects in this way, we can control for the strong cyclical variation in the housing industries observed in figure 1.[37]

Table 1 reports results from equation (2) for the two housing industries from 1987 to 2016, a total of 30 observations. The results, reported as the coefficient for *t*, show that labor productivity increased at a rate of 1.1 percent a year in single-family construction and at 3.7 percent for multifamily construction.[38] The coefficients also show that cyclical variation, as measured by housing starts, has a sizable impact on observed productivity; for example, each 1.0-percent increase in starts is associated with a 0.4-percent increase in observed single-family productivity.

Table 1. Productivity growth in housing—direct labor only, 1987−2016

Variable	Constant	Housing starts	Time	Fit and sample size
Single-family	−20.643	0.414	0.011	$\bar{r}^2 = 0.80$
t-ratios	(−6.13)[(1)]	(7.97)[(1)]	(6.76)[(1)]	$n = 30$
Multifamily	−70.962	0.305	0.037	$\bar{r}^2 = 0.87$
t-ratios	(−13.15)[(1)]	(3.54)[(1)]	(13.67)[(1)]	$n = 30$

Notes:

(1) Indicates significantly different from 0 at the 99-percent level.

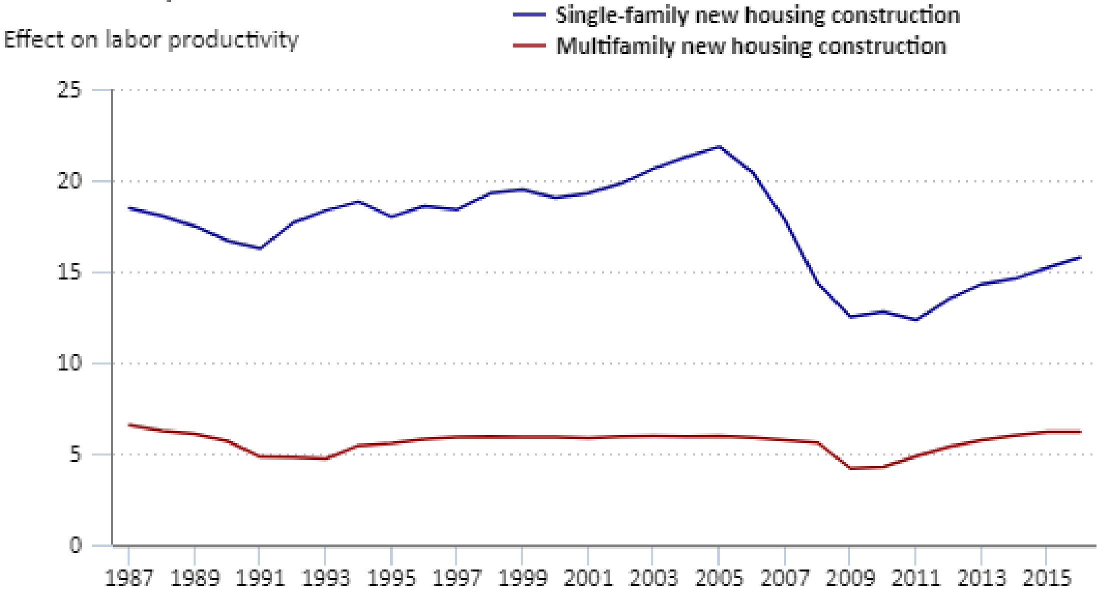
(2) Indicates significantly different from 0 at the 95-percent level.

Notes: Regressions are based on equation (2) in main text. Standard errors and *t*-ratios reflect the Newey-West (Whitney K. Newey and Kenneth D. West, “A simple, positive semi-definite, heteroskedasticity and autocorrelation consistent covariance matrix,” *Econometrica*, vol. 55, no. 3, May 1987, pp. 703−708) correction for autocorrelation. Results are based on a 1-year lag in the error term; similar patterns appear for 2-year lags.

Source: Authors’ calculations.

Figure 4 illustrates the impact of housing starts on observed labor productivity.[39] It graphs the log(*hs*) variable multiplied by its estimated coefficient as reported in table 1 for both housing industries. Housing starts often have a very strong cyclical effect. Cyclical fluctuations had a particularly strong impact on single-family housing, especially over the 2003–10 period.

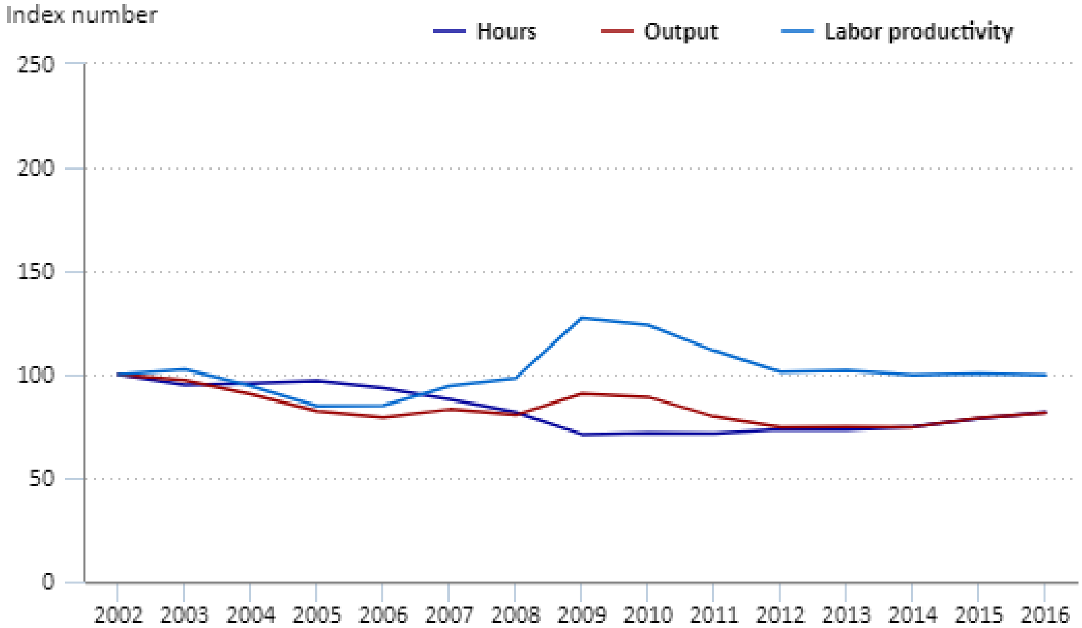
Figure 4. Effects of housing starts on observed labor productivity in single-family and multifamily new housing construction, 1987–2016 (base year 1987 = 100)



Click legend items to change data display. Hover over chart to view data.
Notes: The annual impact of housing starts (hs) is calculated as exp(0.414 • log(hs)) in single-family housing and as exp(0.305 • log(hs)) in multifamily housing. Recession periods are July 1990 to March 1991, March 2001 to November 2001, and December 2007 to June 2009, as determined by the National Bureau of Economic Research.
Source: U.S. Bureau of Labor Statistics.

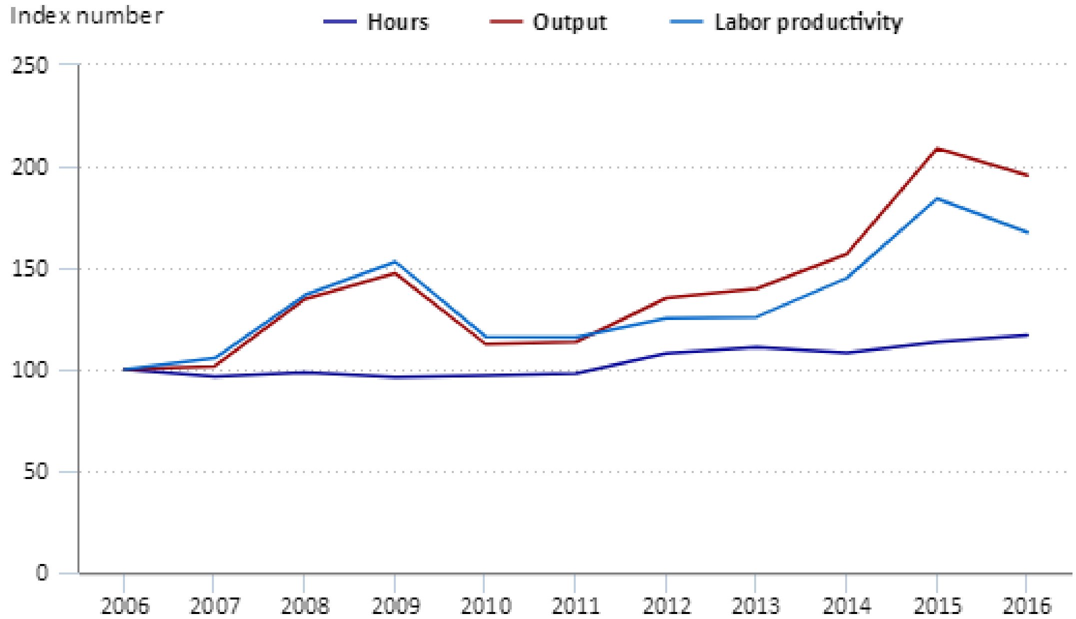
Figures 5 and 6 show the growth of hours, output, and labor productivity for highways construction and industrial construction. Since these two industries are much more stable than the housing industry, productivity growth is measured, as is the usual case, by the annual average rate of productivity growth. These procedures indicate that productivity growth was 0.0 percent a year in highways and 5.3 percent a year in industrial construction.[40]

Figure 5. Index of hours, output, and labor productivity in highways, roads, and bridges construction, 2002–16 (base year 2002 = 100)



Click legend items to change data display. Hover over chart to view data.
Note: The recession period was from December 2007 to June 2009, as determined by the National Bureau of Economic Research.
Source: U.S. Bureau of Labor Statistics.

Figure 6. Index of hours, output, and labor productivity in industrial construction, 2006–16 (base year 2006 = 100)



Click legend items to change data display. Hover over chart to view data.
Note: The recession period was from December 2007 to June 2009, as determined by the National Bureau of Economic Research.
Source: U.S. Bureau of Labor Statistics.

In highways, hours declined, somewhat unexpectedly, after the 2007 recession, despite federal expenditures designed to stimulate highways construction. Extremely tight budgets in many state and local governments most likely held back employment, especially in maintenance and repair. The recession also affected manufacturing severely, so the sharp declines in output and productivity that have occurred in industrial construction after 2007 are not surprising.

Subcontractors

The numbers presented so far measure gross output per hour and are therefore consistent with many widely used measures of labor productivity growth.[41] However, in construction, many builders purchase large amounts of additional labor by using subcontractors, such as carpenters or electricians. The central measures for each of the four industries just presented do not include subcontractors, but including subcontractor labor inputs can provide a more complete picture of labor input.

This subsection examines the implications of including subcontractor labor by allocating their hours to the builders who use these inputs. Each COC collects data on the amount of output that each type of subcontractor (such as carpenters or electricians) provides to each form of construction (such as single-family or highways). The output each type of contractor provides to each form of construction is further subdivided into deliveries to new construction; to additions, alterations, or reconstruction; and to maintenance and repair. The box that follows describes how we use this information to measure the labor hours that contractors supply to each form of construction.

Determining subcontractor labor within each industry

Many builders use specialized subcontractor labor, such as plumbers or carpenters, to supplement or replace their own labor force. In a KLEMS (capital, labor, energy, materials, and purchased services) multifactor productivity framework, subcontractor labor would be accounted for through the purchase of services.[42] Since the present analysis considers only gross-output labor productivity growth, it does not account for services inputs. It is therefore useful to measure the subcontractor labor supplied to each industry and to consider the labor provided by subcontractors (often called "subs" in construction) as a supplementary labor input.

The COC collects data on the amount of output each type of contractor (such as plumbers or carpenters) provides to each form of construction (such as single-family or highways). The COC also shows how much output each type of contractor delivers to each form of construction for new construction; additions, alterations, or reconstruction; and maintenance and repair.

To determine how much labor subcontractors provide to builders in any industry, we assume that subcontractor deliveries (of output) for additions, alterations, or reconstruction are twice as labor intensive (have twice the labor-output ratio) as deliveries for new construction. Similarly, we assume that output delivered for maintenance and repair is 3 times as labor intensive as output provided to new construction. These ratios are assumed to hold true for deliveries from every type of contractor and to remain constant over time. Given these assumptions, we can estimate how much labor a particular type of contractor allocates to each different type of production if we know the fraction of revenues derived from each type of construction.

Assume, for example, that carpenters supply 60 percent of their total output (deliveries to all sectors, not just to home building) to new construction, 20 percent to additions and alterations, and another 20 percent to maintenance and repair. Along with the labor-output ratios of 1, 2, and 3, we can write

$$0.60 \cdot 1x + 0.20 \cdot 2x + 0.20 \cdot 3x = L, \qquad (1)$$

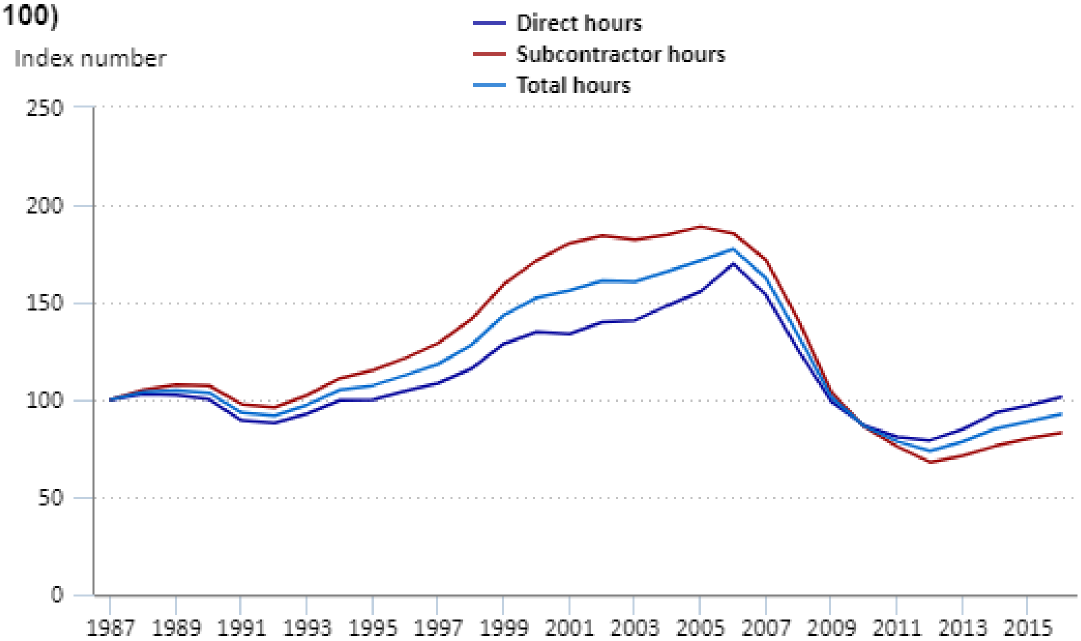
where L is the total labor input employed by carpenters and x helps explain how much labor input is used in each function. The logic of this equation is that the hours committed to new construction plus those to additions, alterations, or reconstruction and those to maintenance and repair sum to the total hours provided. We measure the labor committed to each of these three alternatives by the proportion of output multiplied by the labor-output ratio. Solving equation (1) for x yields $x = L/1.60$. Thus, the fraction of total labor that carpenters supply to new construction is 0.60/1.60, and 0.375 of all carpenter subcontractor labor is delivered to new construction. Once we determine the amount of labor delivered to new construction, this amount can, in turn, be allocated to specific industries. For example, if 80 percent of carpenter output delivered to new construction is supplied to single-family-home building, then we estimate that 30 percent (0.800 × 0.375) of all carpenter contractor labor is supplied to single-family-home building. Once the labor that carpenters, plumbers, roofers, electricians, and every other type of contractor indirectly supply to single-family housing has been established, the sum of labor inputs provided from each source determines total subcontractor labor input. We perform these calculations for each type of contractor in each census year.

Of course, the accuracy of our estimates of contractor labor depends on the validity of the assumed labor-output ratios of 1, 2, and 3. Our earlier studies of construction productivity (SRMPY 2014) shed some light on this approach.[43] We found that residential remodelers (NAICS 236118), which is an important component of housing improvement and repair, have roughly half the output-labor ratio (twice the labor-output requirement) of new housing construction. Many of the contractor industries have considerably lower values of labor-output (higher labor output) requirements. We also consulted with several experts on construction, and the consensus reached was that the 1, 2, and 3 assumption is reasonable.[44] Finally, we examined several alternative labor-output requirements values, such as 1, 2, and 5, and found that such alternatives did not substantially alter our results. We plan to examine the effect of subcontractors more fully once we analyze the COC microdata..

We find that subcontractor labor is an important part of total labor hours. In 2012, subcontractor labor accounted for 44.2 percent of total labor hours in single-family construction, 74.5 percent in multifamily construction, 43.2 percent in highways, and 84.9 percent in industrial construction.

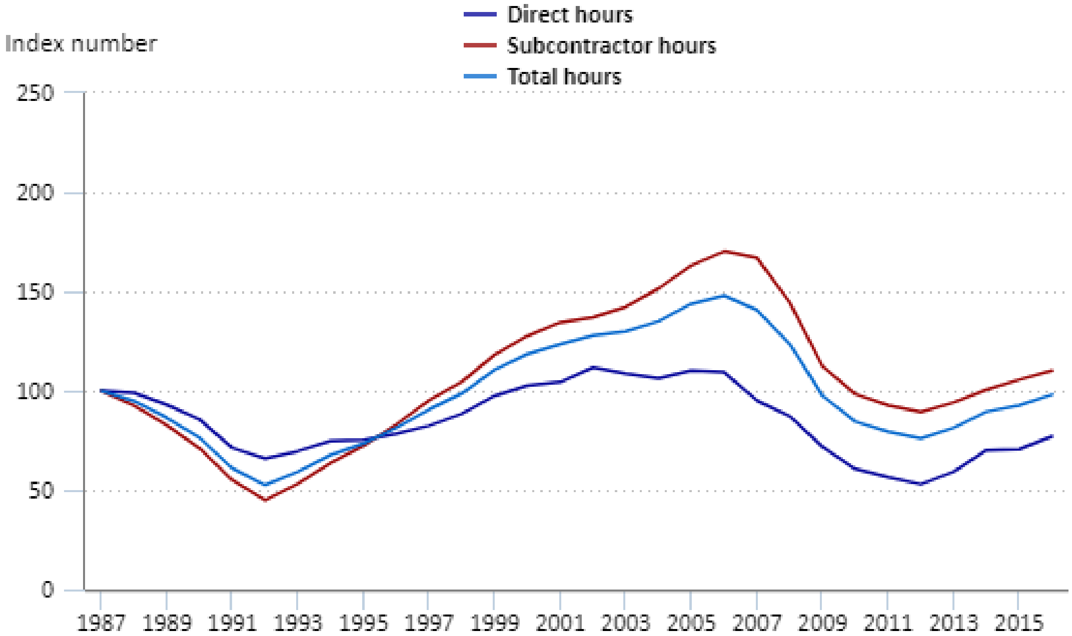
Figures 7A to 7D show the growth of subcontractor labor. Each figure shows direct labor, subcontractor labor, and total labor hours within one of the industries. In two industries, multifamily housing (figure 7B) and highways (figure 7C), subcontractor labor (the red line) grew more rapidly than direct labor (the dark-blue line) and total labor hours (the light-blue line). In the other two industries (single-family housing [panel 7A] and industrial construction [figure 7D]), subcontractor labor grew slightly less than direct labor.

Figure 7A. Index of direct hours, subcontractor hours, and total labor hours in new single-family housing construction, 1987–2016 (base year 1987 = 100)



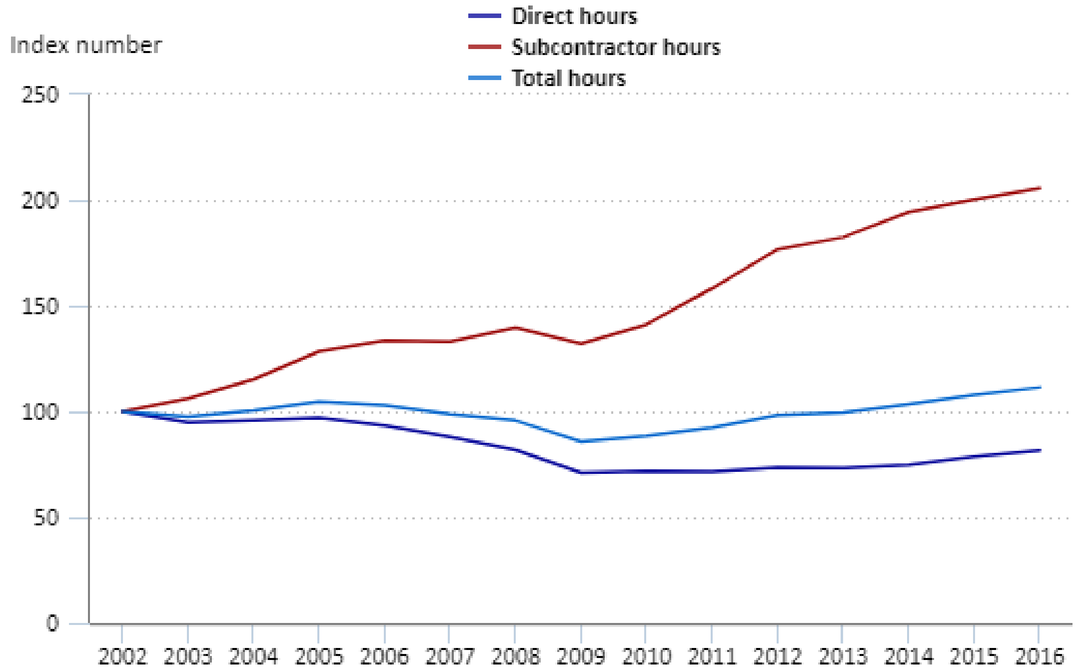
Click legend items to change data display. Hover over chart to view data.
Note: Recession periods are July 1990 to March 1991, March 2001 to November 2001, and December 2007 to June 2009, as determined by the National Bureau of Economic Research.
Source: U.S. Bureau of Labor Statistics.

Figure 7B. Index of direct hours, subcontractor hours, and total labor hours within multifamily housing industry, 1987–2016 (base year 1987 = 100)



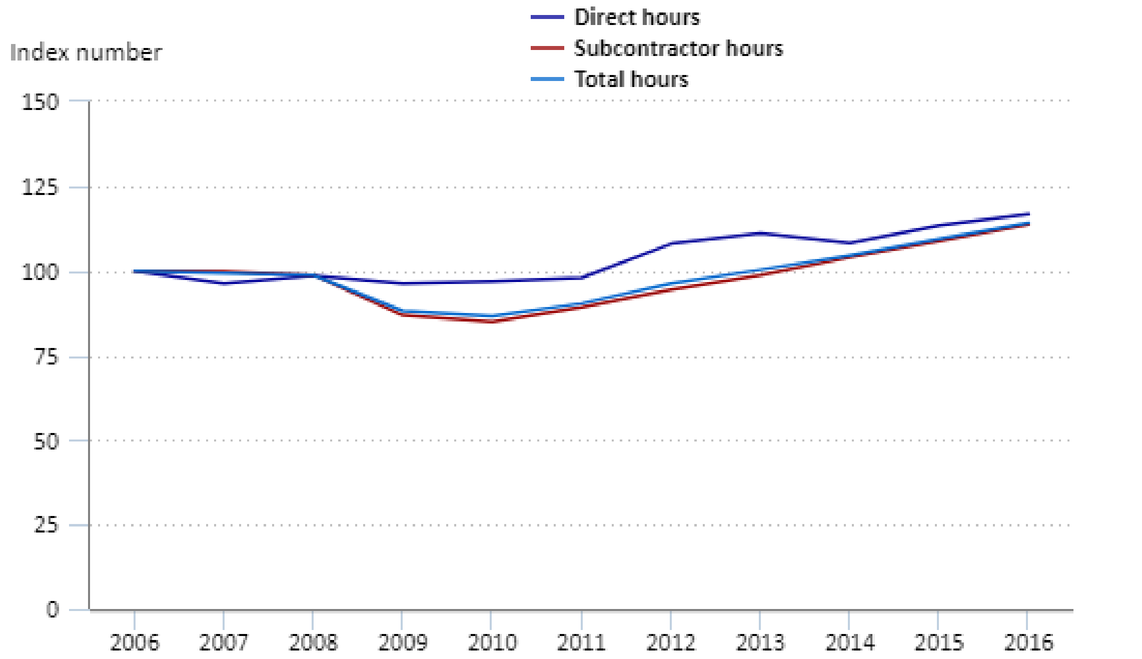
Click legend items to change data display. Hover over chart to view data.
Note: Recession periods are July 1990 to March 1991, March 2001 to November 2001, and December 2007 to June 2009, as determined by the National Bureau of Economic Research.
Source: U.S. Bureau of Labor Statistics.

Figure 7C. Index of direct hours, subcontractor hours, and total labor hours in highways, streets, and bridges industry, 2002–16 (base year 2002 = 100)



Click legend items to change data display. Hover over chart to view data.
Note: The recession period is from December 2007 to June 2009, as determined by the National Bureau of Economic Research.
Source: U.S. Bureau of Labor Statistics.

Figure 7D. Index of direct hours, subcontractor hours, and total labor hours in industrial construction, 2006–16 (base year 2006 = 100)



Click legend items to change data display. Hover over chart to view data.
Note: The recession period is from December 2007 to June 2009, as determined by the National Bureau of Economic Research.
Source: U.S. Bureau of Labor Statistics.

Table 2 reruns the analysis of table 1, on the basis of equation (2), with labor inputs defined as direct plus subcontractor labor. With this expanded concept of labor input, the 1987–2016 rate of productivity growth does not change much, at 1.2 percent a year, in single-family housing but is greatly lower, 1.9 percent a year, in multifamily housing.[45] Figure 8 illustrates productivity trends using the broader definition of labor input. For the 1987–2016 period, all the available evidence (tables 1 and 2, figures 3 and 8) indicates that long-term productivity growth has been positive in both housing industries.

Table 2. Productivity growth in housing—direct and subcontractor labor, 1987-2016

Variable	Constant	Housing starts	Time	Fit and Sample Size
Single-family	–21.974	0.294	0.012	$\bar{r}^2$ = 0.49
t-ratios	(–3.55)[(1)]	(3.69)[(1)]	(4.02)[(1)]	*n* = 30
Multifamily	–33.996	0.25	0.019	$\bar{r}^2$ = 0.57
t-ratios	(–3.68)[(1)]	(2.09)[(2)]	(4.14)[(1)]	*n* = 30

Notes:

[(1)] Indicates significantly different from 0 at the 99-percent level.

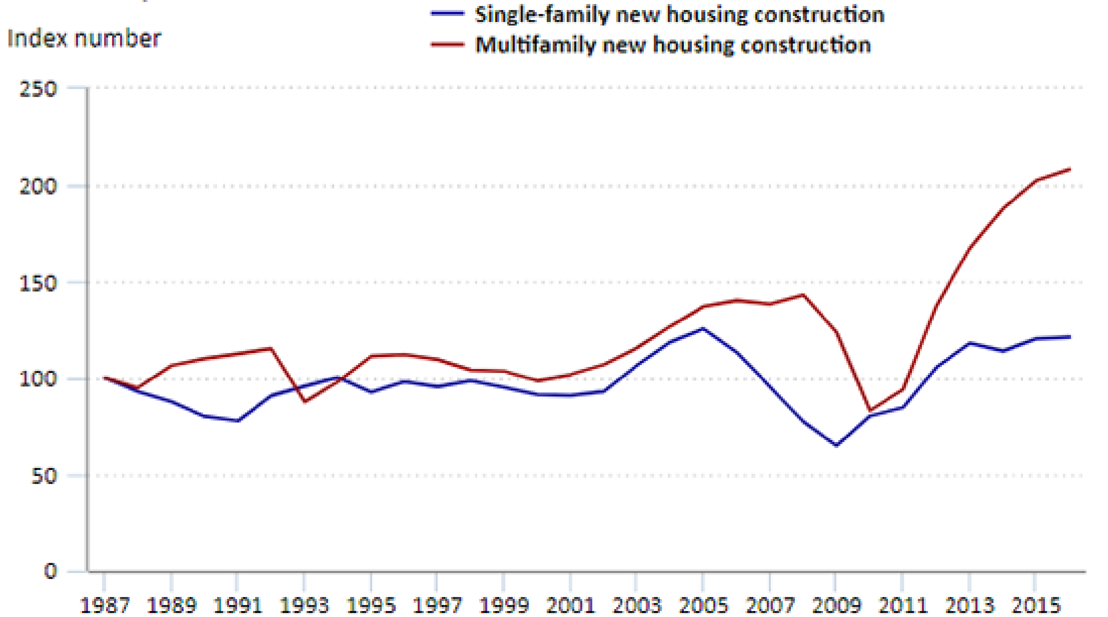
[(2)] Indicates significantly different from 0 at the 95-percent level.

Notes: Regressions are based on equation (2) in main text. Standard errors and *t*-ratios reflect the Newey-West (Whitney K. Newey and Kenneth D. West, “A simple, positive semi-definite, heteroskedasticity and autocorrelation consistent covariance matrix,” *Econometrica*, vol. 55, no. 3, 1987, pp. 703–708) correction for autocorrelation. Results are based on a 1-year lag in the error term; similar patterns appear for 2-year lags.

See footnotes at end of table.

Source: Authors' calculations.

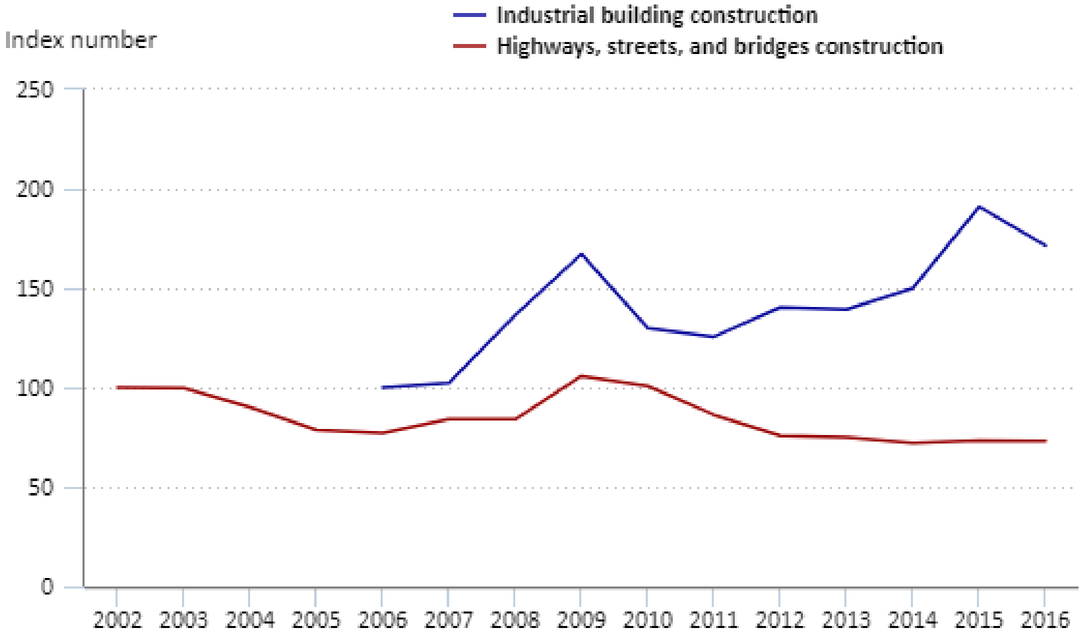
Figure 8. Index of labor productivity in single-family and multifamily new housing construction, includes subcontractor hours, 1987–2016 (base year 1987 = 100)



Click legend items to change data display. Hover over chart to view data.
Note: Recession periods are July 1990 to March 1991, March 2001 to November 2001, and December 2007 to June 2009, as determined by the National Bureau of Economic Research.
Source: U.S. Bureau of Labor Statistics.

Figure 9 shows long-term productivity growth in the two other industries, highways and industrial construction, when we adopt the broader concept of labor.[46] Productivity growth was –2.2 percent a year in highways and 5.5 percent a year in industrial construction. Table 3 summarizes all the relevant estimates of productivity growth, as determined by the various methods and procedures. Except in highways, all estimated growth rates are positive. The regression estimates for single-family housing suggest slightly greater long-term productivity growth than do the compound growth calculations. Labor productivity growth is substantially lower in multifamily housing and in highways when labor inputs include the labor obtained from subcontractors.[47]

Figure 9. Index of labor productivity in highways and industrial construction, includes subcontractor hours (base year 2002 = 100)



Click legend items to change data display. Hover over chart to view data.
Note: The recession period was from December 2007 to June 2009, as determined by the National Bureau of Economic Research.
Source: U.S. Bureau of Labor Statistics.

Table 3. Summary of productivity growth over time in four construction industries

Industry	Direct labor	Direct and subcontractor labor	Years
Single-family housing: regression method	1.1	1.2	1987–2016
Compound growth	0.4	0.7	1987–2016
Multifamily housing: regression method	3.7	1.9	1987–2016
Compound growth	3.4	2.6	1987–2016
Highways (compound growth)	0.0	–2.2	2002–2016
Industrial construction (compound growth)	5.3	5.5	2006–2016

Note: All data in this table report annual rates of labor productivity growth.

Source: Authors' calculations.

Discussion

Many studies have used aggregate data for the entire construction sector and have found that productivity in construction has been stagnant or negative for almost 50 years.[48] Other experts are skeptical that such results can be true. Allmon and colleagues have shown that productivity has increased in many tasks that are typical in construction.[49] Similarly, BLS productivity data report that capital per hour increased 2.0 percent annually in construction from 1987 to 2015; these capital inputs include technology-intensive forms of equipment such as construction machinery and computers.[50]

One central problem is that the deflators typically used to measure construction output have not matched the output they are being used to deflate. As Allen and Pieper note, in the United States, a mixture of the single-family residential deflator and the Turner Construction Cost Index has often been used to approximate output price trends in other segments of construction.[51] These proxy deflators can be misleading for two reasons. First, output price trends in single-family housing could be quite different from trends in other forms of construction. Second, the mixed single-family and Turner proxy deflator includes a construction cost component that is known to be an unreliable indicator of output price.

Our article improves on previous research by using appropriate output deflators to develop measures of productivity growth in four industries in which the deflators are more reliable. The measures are more reliable because the deflators are specifically designed for each industry. Three of the four industries show clear and strong productivity growth. Productivity growth in these industries remains positive if subcontractor labor also is included. This evidence tentatively suggests that productivity growth has been positive in construction. However, the data do not yet include contractors and other portions of construction in which additions, alterations, or reconstruction and maintenance and repair are important. Productivity growth may be slower or negative in these other portions of construction. Therefore, it is too early to conclude that productivity growth has been positive in the construction sector as a whole.[52]

The evidence that productivity growth is positive in some construction industries brings up another question. How does productivity growth in construction compare with growth in other sectors of the economy? To answer this question, we compare productivity growth of our 4 construction industries with growth rates in the 86 four-digit NAICS manufacturing industries and with growth in the 98 five- and six-digit NAICS nonmanufacturing industries included in BLS industry productivity measures.[53] Since the rate of national productivity growth has fluctuated widely over the last 30 years, we compare each of the new industry results with the industry productivity database over the corresponding period.

Table 4 shows that the average annual productivity growth in these construction industries is roughly comparable to productivity growth in nonconstruction industries. However, productivity growth is the slowest in the largest two industries (single-family housing and highways).[54] In addition, the industries considered here accounted for only about 11 percent of the total hours in construction in 2012.[55] Therefore, it is still too early to determine whether productivity growth is greater in construction than in other industries. However, the evidence from the individual industries provides little support so far for the hypothesis that the rate of productivity growth has been abnormally slow in construction.[56]

Table 4. Comparison of productivity growth in construction industries with productivity growth in the nonfarm business sector in the corresponding years

Industry	Years	Direct labor	Direct and subcontractor labor	Average productivity growth		
				Total	Manufacturing	Nonmanufacturing
Single-family	1987–2015	1.1	1.1	2.2	2.0	2.4
Multifamily	1987– 2015	3.7	1.7	2.2	2.0	2.4
Highways	2002–2015	0.0	−2.4	1.6	1.2	2.0

See footnotes at end of table.

Table 4. Comparison of productivity growth in construction industries with productivity growth in the nonfarm business sector in the corresponding years

Industry	Years	Direct labor	Direct and subcontractor labor	Average productivity growth		
				Total	Manufacturing	Nonmanufacturing
Industrial construction	2006–2015	7.0	7.5	0.8	0.3	1.3

Notes: The total column under "Average productivity growth" refers to the total industries included in the Division of Industry Productivity Studies database, including both the industries in manufacturing and nonmanufacturing. The last three columns (also under "Average productivity growth") refer to unweighted averages of all the individual industries, rather than a weighted average. We use unweighted averages so that one can more readily compare the construction industries with a typical industry in the database. In contrast to the main text, table 4 examines data only up to 2015 because measures for some of the comparison industries have not yet been updated to 2016. All data in this table report annual rates of labor productivity growth.

Source: Authors' calculations.

Rates of productivity growth in construction are considerably lower in two industries when subcontractor labor is included.[57] However, substitution of purchased labor for core labor, such as the outsourcing of guard or bookkeeping services to outside vendors or consultants, occurs in many other industries. No comprehensive database exists that measures the outsourcing of labor in many industries. Therefore, the only accurate comparison one can make from table 4 is between the direct labor inputs and similar measures for additional industries. By that standard, productivity growth in construction is not appreciably slower than in the rest of the economy.[58]

As a historical note, the Office of Productivity and Technology of the BLS conducted many studies of labor-input requirements in different portions of construction. Most of these studies were conducted in the 1970s or 1980s. The program on construction labor-input requirements was closed in the early 1980s because of budgetary limitations. The box that follows describes the work conducted within this program.

Prior Office of Productivity and Technology work on construction

Years ago, mainly in the 1970s and 1980s, the Office of Productivity and Technology conducted a number of studies on the construction sector. The results were published in various BLS Bulletins and *Monthly Labor Review* articles.

These early studies included three of the four industries covered in the present article: single-family homes, multifamily homes, and highways. These studies also examined federal office buildings, hospitals, commercial office projects, and schools. Other articles considered college dormitories and sewer lines.

References to this work include

Ball, Robert. "Employment created by construction expenditures." *Monthly Labor Review*, December 1981, pp. 38–44. https://stats.bls.gov/opub/mlr/1981/12/art5full.pdf.

Ball, Robert, and Joseph T. Finn. “Labor and materials requirements for sewer works construction.” *Monthly Labor Review,* November 1976, pp. 38–41.

Ball, Robert and Larry Ludwig. “Labor requirements for construction of single-family homes.” *Monthly Labor Review*, September 1971, pp. 12–14.

Bingham, Barbara J. “Labor and material requirements for commercial office building projects.” *Monthly Labor Review*, May 1981, pp. 41–48.

Bingham, Barbara J. “Labor requirements for college-housing construction.” *Monthly Labor Review*, May 1979, pp. 28–34.

Finger, Diane C. “Labor requirements for federal highway construction.” *Monthly Labor Review*, December 1975, pp. 31–36.

Murray, Roland V. “Labor requirements for federal office buildings.” *Monthly Labor Review*, August 1962, pp. 889–893.

Olsen, John G. “Labor and material requirements for federal building construction.” *Monthly Labor Review*, December 1981, pp. 47–51.

Olsen, John G. “Labor and material requirements for new school construction.” *Monthly Labor Review*, April 1979, pp. 38–41.

Prier, Robert J. “Labor and material requirements for federally-aided highways.” *Monthly Labor Review*, December 1979, pp. 29–34.

Prier, Robert J. “Labor requirements decline for public housing construction.” *Monthly Labor Review*, December 1980, pp. 40–44.

Rothberg, Herman. *Labor and Material Requirements for Private Multifamily Housing Construction*. Bulletin 1892. Washington, DC: U.S. Bureau of Labor Statistics, 1976, pp. 69.

Rothberg, Herman. “Labor requirements for hospital construction, 1959–60.” *Monthly Labor Review*, October 1962, pp. 1,120–1,124.

Topkis, Bernard H. “Labor requirements in the production of clay products.” *Monthly Labor Review,* December 1937, pp. 1,391–1,410.

U.S. Bureau of Labor Statistics. *Labor Requirements for Construction Materials, Part I—Portland Cement, Part II—Concrete Masonry Units, and Part III—Concrete Pipe*. Bulletin 888. Washington, DC: U.S. Government Printing Office, 1947.

The focus of the construction-input-requirement program was to measure labor employment per unit of output or how much employment could be obtained for a given expenditure of output. Some of these studies examined how these requirements changed over time. These estimates were considered useful in guiding macroeconomic policy. Information on labor-input requirements shows the amount of employment that increased expenditures in any field of construction can generate.

At the time that the studies were conducted, reliable output price deflators were not available, so the work of the Office of Productivity and Technology on labor-input requirements was never converted into acceptable measures of productivity growth over time. The entire construction-input-requirements program was abandoned in the early 1980s because of budgetary pressures.

Measuring productivity growth in additional portions of construction

As we noted earlier, the PPI program has started publishing deflators for a number of detailed additional portions of construction.[59] The PPI now publishes measures for the construction of warehouses, schools, offices, healthcare buildings (including medical offices and hospitals), and industrial buildings. The PPI also publishes deflators for contractor services, which includes electricians, plumbers (including heating and air conditioning), roofers, and concrete contractors; however, each of these contractor deflators covers only nonresidential construction.

In this study, we used only one of these deflators (for industrial construction). The many new deflators open up the possibility of covering additional construction industries. Unfortunately, the PPI classifications do not match the NAICS codes for construction industries. For example, warehouses, schools, offices, and healthcare buildings are all part of NAICS 236220, commercial and institutional building construction. NAICS 236220 also includes many additional types of buildings, such as shopping centers, churches, and police stations. Similarly, plumbing contractors, except residential, make up only one part of NAICS 238220, plumbing, heating, and air conditioning contractors.[60]

Therefore, to obtain measures of output and labor input compatible with the new PPIs, we need to use the COC microdata to determine exactly which establishments specialize in the construction of warehouses or offices or which contractors specialize in nonresidential construction. Once we have reclassified the COC establishments in a way that is consistent with the new PPIs, we can easily add the output and employment (including P&Ps) observed in each PPI category.[61]

Access to COC microdata also opens up the possibility of answering further questions about construction. For example, it will be possible to examine the extent to which productivity varies across establishments within these construction industries and whether economies of scale play a role in this variation. The BLS productivity program hopes to continue this research effort and to determine whether it is possible to prepare reliable measures of multifactor productivity growth for selected industries in construction. However, any such plans are subject to the availability of resources.

Conclusions

This article has presented measures of productivity growth in four industries in construction. The results so far suggest that, contrary to earlier studies, productivity growth has typically been positive. This evidence contrasts sharply with the aggregate evidence, which indicates that productivity growth in construction, as a whole, has been negative or zero for half a century.

There is good reason to doubt the aggregate estimates. Specifically, the deflators used to construct these estimates do not account for the broad range of construction activity. Our estimates, which use deflators that more closely match industry output, indicate that productivity in three of the four industries has been positive and robust over our sample period. Further research on additional portions of construction, using COC microdata and the new PPIs, will help fill out the overall picture.[62]

Appendix

Self-employed worker hours

We estimate self-employed worker hours as the number of self-employed workers multiplied by their average weekly hours. We estimate the number of self-employed workers as the number of partnerships multiplied by the number of partners per partnership plus the number of sole proprietors. Data on the number of partners and sole proprietors come from the Census of Construction (COC). The number of partners per partnership comes from the Internal Revenue Service (IRS) publication “Statistics of Income.”[63] Average weekly hours come from the Current Population Survey.

The COC publishes data on the number of P&Ps for establishments with payroll and without payroll. Most of the labor input of P&Ps occurs in establishments classified as without payroll.

In 1987 and 1992, the P&P data were published in a COC volume on “Legal Form of Organization and Type of Operation,”[64] with separate estimates for establishments with or without payroll. In 1997 and subsequent census years, data on P&Ps for establishments with and without payroll were published in separate reports. The Legal Form of Organization portion of the COC continued to publish the number of establishments with P&Ps, using a six-digit code, for those establishments with payroll. To form a continuous time series for those establishments with payroll, we interpolated the number of six-digit P&Ps, with payroll, between census years.[65] Data on P&Ps in establishments without payroll were transferred to the new report on Nonemployer Statistics,[66] but these data were published only in a four-digit North American Industry Classification System (NAICS) code. We used the six-digit detail from establishments with payroll to allocate the four-digit P&Ps without payroll to specific six-digit NAICS industries. We did this for each year from 1997 to 2016.[67] Information on the number of partners per partnership comes from the IRS publication, “Statistics of Income, Tax Notes,”[68] which is available by year starting in 1997. Tax Notes reports some industry detail on the number of partners per partnership. The average number of partners per partnership is approximately 2.9 in construction, although the number varies by year and industry. For years before 1997, we used the 1997 number of partners per partnership in each industry.[69]

The BLS Current Population Survey is the only source for hours worked by P&Ps. The census industry codes used in the Current Population Survey provide no detail on specific construction industries. Therefore, we assumed that average weekly hours of P&Ps wee the same in each construction industry and equal to the overall average for construction.[70] As in the earlier treatment of employee hours, we multiplied the number of P&Ps by their average weekly hours and multiplied that total by 52 to arrive at the total hours worked by self-employed workers in each industry in construction in each census year.

As just noted, the number of P&Ps has to be interpolated between the 1987 and 1992 censuses and between the 1992 and 1997 censuses. We benchmarked self-employment to the corresponding series for paid employees in each industry.[71]

Interpolation between census years

Output, employee hours, and P&P hours must be estimated for noncensus years for one to calculate annual labor productivity measures. Two central decisions must be made in preparing such imputations. First, which series should we use to interpolate the different data elements between census years? Second, if the census data and the interpolating data series exhibit different 5-year growth rates between census years, how is this discrepancy resolved? The present subsection addresses these two issues.

The “Value of Construction Put in Place” report from the U.S. Census Bureau provides good information on the annual growth of output between census years.[72] However, the growth rate of output in the “Value Put in Place” data typically differs from the growth rate in the COC data. In these circumstances, as explained in SRMPY 2014,[73] we benchmarked our interpolating series to the actual COC data and assumed that one-fifth of the entire 5-year discrepancy occurs in each of the 5 years between actual census data. This assumption smooths out the annual discrepancy between our interpolating variable and the actual COC data.

For years beyond the most recent COC, it is necessary to extrapolate using the Value Put in Place data. This procedure is the same, except that benchmarking is not possible. For example, we used the Value Put in Place data to estimate the growth in construction output for 2013, 2014, 2015, and 2016. Once the 2017 COC data have been published, benchmarking the extrapolated annual estimates to the actual data reported in the 2017 census will be possible as just described. We use similar procedures to interpolate and extrapolate employment from the COC, using the corresponding annual information from the BLS Current Employment Statistics program.

SUGGESTED CITATION

Leo Sveikauskas, Samuel Rowe, James D. Mildenberger, Jennifer Price, and Arthur Young, "Measuring productivity growth in construction," *Monthly Labor Review,* U.S. Bureau of Labor Statistics, January 2018, https://doi.org/10.21916/mlr.2018.1

NOTES

1 Michael J. Harper, Bhavani Khandrika, Randal Kinoshita, and Steven Rosenthal, “Nonmanufacturing industry contributions to multifactor productivity, 1987–2006,” *Monthly Labor Review*, June 2010, https://www.bls.gov/opub/mlr/2010/06art2full.pdf; and Paul Teicholz, “Labor-productivity declines in the construction industry: causes and remedies (another look),” *AECbytes*, March 14, 2013, https://www.aecbytes.com/viewpoint/2013/issue_67.html.

2 The data on aggregate output in construction come from the National Income and Product Accounts (NIPA) of the Bureau of Economic Analysis (BEA). The *NIPA handbook: concepts and methods of the U.S. National Income and Product Accounts*, February 2014, provides information on the output price deflators used. Chapter 6, “Private fixed investment,” and especially table 6.A, “Summary of methodology used to prepare estimates of private fixed investment in structures,” describe the procedures used. For more information, see https://apps.bea.gov/national/pdf/allchapters.pdf. In prior years, relatively little information was available on output price deflators in construction. However, beginning in 2005, many new deflators became available, which the BEA immediately adopted. The improved new deflators considerably improved the aggregate numbers for construction. Nevertheless, the aggregate numbers for construction still contain proxy deflators assumed correct for certain portions of construction. Measures based on deflators known to be appropriate for specific industries are therefore still preferable to the existing aggregate data.

3 Building Futures Council, "Measuring productivity and evaluating innovation in the U.S. construction industry," white paper (Arlington, VA: Building Futures Council, 2006), p. 2, https://pdfs.semanticscholar .org/b906/4bc6d99a043f67cf75aa0ba62830d373245c.pdf. Some of our main empirical results were first reported in Leo Sveikauskas, Samuel Rowe, James Mildenberger, Jennifer Price, and Arthur Young, "Productivity growth in construction," *Journal of Construction Engineering and Management*, vol. 142, no. 10, October 2016, https://ascelibrary.org/doi/abs/10.1061/ (ASCE)CO.1943-7862.0001138. We refer to this article as "SRMPY 2016." See also BLS Working Paper 478, an earlier version of the 2016 article published in October 2014, https://www.bls.gov/osmr/research-papers/2014/ec140090.htm. The working paper version includes much more detail on how the estimates were prepared. In the present article, we refer to that paper as "SRMPY 2014."

4 The new Producer Price Index estimates of construction output prices do not depend on sales prices for actual buildings. The BLS establishes a building with standardized features, collects information on the cost of this standardized building from many builders, and gathers complementary information on profit margins beyond these costs. Justin M. Harper provides a detailed description of how these new PPIs are prepared in "Examining trends in the nonresidential building construction producer price indexes (PPIs)," *Beyond the Numbers: Prices and Spending*, vol. 3, no. 10, May 2014 (U.S. Bureau of Labor Statistics), https://www.bls.gov/opub/btn/volume-3/examining-trends-in-the-nonresidential-building-construction-producer-price-indexes-ppis.htm?view_full.

5 The BLS Office of Productivity and Technology measures productivity growth in all construction as part of the major-sector measures, which are partially based on data from the National Income and Product Accounts. However, output and the corresponding inputs are often difficult to measure outside manufacturing and can produce productivity measures of inconsistent quality. Readers should be cautious in interpreting such data. See https://www.bls.gov/mfp/special_requests/klemsmfpxg.zip and https://www.bls.gov/opub/mlr/2010/06/art2full.pdf for current measures and background methodology. As one example of the usefulness of the major-sector database, these data indicate that partners and proprietors (P&Ps) accounted for 19 percent of total hours worked in construction in 2012. Throughout the current article, labor hours always include P&Ps.

6 Consistent with standard practice in statistical agencies, all construction is referred to as the construction sector. Similarly, production in portions of the construction sector, such as in single-family housing or highways, is described as occurring in industries. This matter is worth clarifying here because portions of the existing construction literature, such as Eddy M. Rojas and Peerapong Aramvareekul, "Is construction labor productivity really declining?" Journal of Construction Engineering and Management, vol. 129, no. 1, February 2003, sometimes use the opposite nomenclature, referring to construction in general as an industry and to portions of construction as sectors.

7 In 1987 and 1992, the U.S. Census Bureau called the section on construction the Census of Construction Industries and it has been referred to unofficially as the Census of Construction. For more information on the history of COC, see https://www.census.gov/library/publications/1996/econ/cc92-i.html.

8 The data for single-family and multifamily housing refer largely to new construction. Additions, alterations, or reconstruction and maintenance and repair conducted on residential housing primarily appear in residential remodelers, NAICS 236118. We do not include residential remodelers because a reliable output price deflator is not available for that industry. Some elements of additions, alterations, or reconstruction and maintenance and repair are included as secondary products.

9 For-sale builders are builders who produce homes on land that they own or control, rather than on land the customer owns. These builders typically construct houses on their own account and eventually sell the house to a buyer.

10 See Sveikauskas et al., "Productivity growth in construction," Working Paper 478, p. 69. The for-sale builders industry was called "operative builders" before 2012. Operative builders were first separated from single-family and multifamily builders in 2002, so the bridge tables for that year are appropriate. Over 95 percent of the revenue and employment of for-sale builders is allocated to single-family housing.

11 Industrial construction consists of structures that permit production in manufacturing. Unlike the two housing industries, highways and industrial construction include additions, alterations, or reconstruction and maintenance and repair as well as new construction.

12 For example, the Division of Industry Productivity Studies (a BLS division in the Office of Productivity and Technology) measures gross output in each industry as the sum of all production from establishments classified in that industry. Most other statistical agencies use this convention.

13 Primary products are those typically produced within a given industry, and secondary products are those goods and services normally produced in other industries. For example, actual single-family homes are the primary product in single-family housing, whereas architectural drawings or roads are examples of secondary products. Each COC contains detailed information on the value of primary and secondary products for each industry. In 2012, secondary products accounted for 8 percent of production in single-family construction, 19 percent in multifamily construction, 13 percent in highways, and 29 percent in industrial construction. In any construction industry, secondary products include both output normally produced in other construction industries and all output outside construction.

14 The measure of revenue also contains work done by subcontractors. The COC treats subcontracting as a purchase of materials, similar to other materials purchases or expenditures on fuels and electricity. Purchases from subcontractors are therefore appropriately included within gross output. Information on the value of business done is generally available for establishments with payroll in each industry. However, in some instances, the value of business done is not available for establishments without payroll. In these cases, business done is estimated for establishments without payroll through the procedures described in SRMPY 2014. (See Sveikauskas et al., "Productivity growth in construction," Working Paper 478, pp. 66–67.) For the industries considered in this article, establishments without payroll typically account for a relatively small share of business done.

15 For more information on the "Value of construction put in place," go to the U.S. Census Bureau website at https://www.census.gov/econ/overview/co0300.html.

16 Single-family and multifamily deflators also are available before 1987. However, our database does not contain as much detail on the output price of secondary products in years before 1987. Information on some elements of labor input is similarly more limited before 1987.

17 The National Highway Construction Cost Index begins in 2003, so the older bid price index is used to carry the data back to 2002. Because of this action, we can include data for an additional census year.

18 John C. Musgrave, "The measurement of price changes in construction," *Journal of the American Statistical Association*, vol. 64, no. 327, September 1969, pp. 771–786.

19 The U.S. Census Bureau reports several alternative price indexes for single-family residential construction. The price index for houses under construction is used because it is more appropriate than the index for new single-family houses sold, which also reflects the value of the lot and certain other costs outside the bounds of construction. The U.S. Census Bureau prepares several alternative price indexes for houses under construction. Of these, we use the Fisher Ideal Index instead of the Laspeyres or Paasche indexes. As the U.S. Census Bureau states about the Fisher Ideal Index for housing, "This index can be used as a price deflator in determining the constant dollar of today's output of houses under construction, which is included in the Gross Domestic Product." See https://www.census.gov/construction/cpi/pdf/generalinformationaboutpriceindexes.pdf.

20 So-called "hedonic" procedures estimate the value of a house in terms of its set of characteristics. For example, an extra square foot may add $50 of value and an additional bathroom may add $20,000. Once each of these characteristics is valued, determining how much housing output has increased is easy because the characteristics of new houses have improved over time. In figure 1 of this present article, the light-blue line shows how the average quality of new single-family homes has improved over time.

21 Frank de Leeuw, "A price index for new multifamily housing," *Survey of Current Business*, vol. 73, no. 2, 1993, pp. 33–42.

22 The exact series is from table 5.4.4 of the National Income and Product Accounts, Bureau of Economic Analysis, entitled, "Price indexes for private fixed investment in structures by type," found at https://www.bea.gov/, Section 5: Saving and Investment.

23 On July 19, 2017, the Federal Highway Administration revised the National Highway Construction Cost Index to version 2.0. The index now increases more rapidly than in version 1.0, so productivity growth in highways is consistently lower than we initially

reported in SRMPY 2014, p. 20, and SRMPY 2016 (no page). The sharp adjustments suggest that the highways deflator is not as well established as the three other deflators we use, which are rarely substantially revised.

24 For more information, see U.S. Department of Transportation, Federal Highway Administration, at https://www.fhwa.dot.gov/policy/otps/nhcci/.

25 See Sveikauskas et al., "Productivity growth in construction," Working Paper 478, p. 8. Different agencies define maintenance and repair of highways in different ways, but this category includes patching the road surface, signs, and guardrails; removing snow and ice; mowing; picking up trash and collecting tolls. Some of these categories, such as patching of road surfaces and guardrails, are likely to fall into the construction industry, and other elements will not. We choose to use the National Highway Construction Cost Index (NHCCI) deflator to deflate those elements of maintenance included in the COC, because items such as patching of road surfaces and guardrails are similar to new construction. (The Producer Price Index produces an index for the cost of maintenance and repair construction in nonresidential construction [series BMNR], but this includes many different forms of construction, such as highways, office buildings, and schools, in which the costs of maintenance and repair may be quite different.) The NHCCI deflator is in some respects not as comprehensive as the well-known single-family and multifamily deflators. First, the NHCCI does not contain hedonic analysis, the method through which the residential deflators adjust for quality improvements over time. Second, NHCCI deflators rely on the winning bids amount, not actual final payments, which may differ through subsequent change orders.

26 Like other Producer Price Index series, the price index for industrial construction is a Laspeyres (base-year) index.

27 Sveikauskas et al., "Productivity growth in construction," Working Paper 478, pp. 9–10, 67–69.

28 A Törnqvist index of output essentially measures the growth of each commodity through its geometric mean of annual output increases. Each commodity's contribution is weighted by its share of total expenditures.

29 Rojas and Aramvareekul, "Is construction labor productivity really declining?"

30 Sveikauskas et al., "Productivity growth in construction," Working Paper 478, pp. 76–77.

31 In 2012, partners and proprietors (P&Ps) accounted for 46.5 percent of direct labor hours in new single-family construction, 12.9 percent in new multifamily construction, 1.8 percent in highways, and 6.6 percent in industrial construction. P&Ps are especially important in many of the contractor industries, such as plumbing or electrical contractors.

32 This article does not include the hours of unpaid family members. These hours are minor in construction.

33 All other BLS measures of unit labor costs cover only the labor directly employed in a particular sector or industry. To ensure that the estimates in the construction industries considered here are comparable, we do not include the cost of labor obtained through subcontractors.

34 The National Association of Home Builders (NAHB) estimated the average time from obtaining a permit to completing construction at 7.0 months for single-family homes and 12.5 months for multifamily housing. The NAHB obtained information from the 2012 Survey of Construction and published the estimates in their blog on housing called *Eye on Housing* by Natalia Siniavskaia, "How long does it take to build a house?" October 21, 2013, at http://eyeonhousing.org/2013/10/how-long-does-it-take-to-build-a-house/, and by Robert Dietz, "How long does it take to build multifamily housing?" November 15, 2013, http://eyeonhousing.org/2013/11/how-long-does-it-take-to-build-multifamily-housing/. The 2015 Survey of Construction data continue to show that permit-to-construction lags are greater for multifamily housing.

35 Throughout this article, labor inputs are measured by labor hours worked. As mentioned in endnote 5, hours always include the hours of partners and proprietors.

36 Colleagues and reviewers from other federal agencies have suggested, in personal conversations, that observed productivity growth is probably overstated in housing booms because unmeasured off-the-books immigrants enter the industry. Conversely, as housing declines, productivity declines are similarly exaggerated because many of the same unmeasured immigrants leave the industry. While such an interpretation seems likely, quantifying such effects is difficult because little is known about off-the-books workers. Our 2014 Working Paper 478 (SRMPY 2014—Sveikauskas et al., "Productivity growth in construction," p. 15, especially footnotes 19 and 20) discusses the 2004–07 boom and the ensuing crash further. Our 2016 article (SRMPY 2016—Sveikauskas et

al., "Productivity growth in construction, *Journal of Construction Engineering and Management*") shows that increased amounts of off-the-books undocumented immigrants probably overstate long-term productivity growth in overall construction by only 0.1 or 0.2 percent a year. We hope to examine the shorter-term effect of undocumented immigrants, especially in housing, further in future work. In a personal conversation with the authors, Ken Simonson, chief economist of the Associated General Contractors of America, suggested that in many areas of construction, crews of workers, especially concrete and wallboard installers, electricians, and plumbers, can work on either residential or nonresidential projects. Simonson believes that many workers employed by and counted in nonresidential construction were drawn into housing during the boom and left housing in the ensuing collapse. Such unmeasured labor shifts could similarly exaggerate the cyclical variation observed in housing productivity, overstating productivity gains in the boom and also exaggerating productivity declines in the crash. Simonson emphasizes that these possibilities illustrate the importance of accurate information regarding the employees engaged in residential or nonresidential work. The rapid productivity increase observed in multifamily housing in 2012–15 also is an outlier. We suspected that this implied rapid productivity growth might partially reflect a shift toward more multifamily building in higher priced cities. However, an analysis of census data on housing permits in each metropolitan area, along with 2012 Bureau of Economic Analysis data on regional price parities for rents in metropolitan areas, showed that the average multifamily unit shifted to higher price areas over time, with average index values of 106.6 in 2012, 108.7 in 2014, and 113.0 in 2015. Multifamily units did grow more quickly in high-priced areas, but this shift was only sufficient to increase implied productivity growth by 1 or 2 percent a year. Nevertheless, such evidence is useful; it shows how observed productivity can vary solely because of shifts in the composition of output without any necessary changes in the underlying technical conditions under which output is produced. The anomalous behavior of multifamily housing during these years may also reflect increasing amounts of off-the-books workers. However, in the absence of more specific information, we cannot determine exactly what caused the rapid rate of productivity growth observed in new multifamily residential construction in recent years. Therefore, we advise readers to view results for this industry over the last few years with some caution.

37 The economics literature often uses capacity utilization as a method of adjusting for cyclical fluctuations in productivity. In a sense, the housing-starts variable similarly adjusts for capacity-utilization effects.

38 In contrast, if we measured productivity growth by calculating average productivity growth between endpoints, productivity growth would be 0.4 percent in single-family construction and 3.4 percent in multifamily construction.

39 The annual effect is measured as $\exp(0.414 \cdot \log(hs))$ for single-family housing and as $\exp(0.305 \cdot \log(hs))$ for multifamily housing.

40 This article reports that the 2006–16 rate of productivity growth was 5.3 percent in industrial construction. Our 2016 article (Sveikauskas et al., "Productivity growth in construction," *Journal of Construction Engineering and Management*) reported the 2006–14 rate as 2.4 percent. However, this difference reflects an error in our earlier calculations. With the new corrected data, the 2006–14 rate should have been 4.8 percent.

41 Standard BLS measures of industry productivity use sectoral output, which is gross output less materials purchased from within the same industry. Since we do not know exactly which materials each construction industry purchases, we are unable to measure sectoral output. Therefore, we measure output by gross output instead. The same problem often occurs in many services industries; measures of industry productivity growth in the services often have to be expressed in terms of gross output.

42 For more information on KLEMS, see https://www.bls.gov/mfp/.

43 See Sveikauskas et al., "Productivity growth in construction," Working Paper 478 (especially table 7 on page 43).

44 Conversations with colleagues and experts from other federal agencies.

45 Average annual productivity growth from 1987 to 2016 was 0.7 percent in single-family construction and 2.6 percent in multifamily construction when subcontractor labor was also included.

46 For housing, long-term data referred to the 1987–2016 period. For the two additional industries, the periods examined are much briefer, 2002–16 and 2006–16, respectively.

47 The measures presented in this article include regression estimates that adjust for cyclical fluctuations and other estimates that allow for subcontractor labor. These additional series provide further insights and information about construction productivity. However, the reader should be aware that when the construction data are updated annually, BLS will emphasize the data series that measures the annual productivity growth of directly employed labor. The BLS prepares consistent data on the productivity of directly employed labor in many different industries, which makes it much easier to compare productivity trends across industries. Consistent data make productivity comparisons across industries much more reliable.

48 Harper et al., “Nonmanufacturing industry contributions to multifactor productivity, 1987–2006,” pp. 16–31, https://www.bls.gov/opub/mlr/2010/06/art2full.pdf; Teicholz, “Labor-productivity declines in the construction industry,” pp. 1–11; and Sveikauskas et al., “Productivity growth in construction,” Working Paper 478 (SRMPY 2014). SKMPY 2014, section I, shows that the data for total construction suggest that labor productivity has been stagnant for many years. SRMPY 2014 includes information for each decade, which shows that such patterns are longstanding and do not merely reflect the difficulties the sector has experienced since 2007.

49 Eric Allmon, Carl T. Haas, John D. Borcherding, and Paul M. Goodrum, “U.S. construction labor productivity trends, 1970–1998,” *Journal of Construction Engineering and Management*, vol. 126, no. 2, March 2000, pp. 97–104.

50 For more information, see https://www.bls.gov/mfp/special_requests/klemsmfp.xlsx.

51 Steven G. Allen, “Why construction industry productivity is declining,” *The Review of Economics and Statistics*, vol. 67, no. 4, November 1985, pp. 661–669; and Paul E. Pieper, ”The measurement of construction prices: retrospect and prospect,” in Ernst R. Berndt and Jack E. Triplett, eds., *Fifty Years of Economic Measurement: The Jubilee of the Conference on Research in Income and Wealth* (Chicago: University of Chicago Press, 1991), pp. 239–271, https://www.nber.org/chapters/c5978.

52 The text so far has developed evidence for productivity growth within buildings (housing, industrial construction) and within heavy construction (highways). However, no evidence has yet been presented for contractors. Two difficulties limit what can be said about productivity growth among contractors. First, the available evidence covers only the 2007–12 period, during which, as the discussion of housing has demonstrated, rapid output declines can bring concomitant declines in productivity growth. Second, the available Producer Price Index (PPI) deflators refer to only the nonresidential component of each contractor industry, whereas the existing productivity information covers each contractor industry, both residential and nonresidential. Nevertheless, in the spirit of full disclosure, this endnote applies the nonresidential deflator to each corresponding full contractor industry. The 2007–12 estimates of annual productivity growth are then as follows:

Industry	*Annual output growth (percent)*	*Annual productivity growth (percent)*
Concrete contractors	–11.51	–3.06
Roofing contractors	–6.70	–5.04
Electrical contractors	–1.43	1.38
Plumbing contractors	–4.01	–1.63

These results certainly suggest that productivity growth may have been negative in the important contractor industries. The problem is that no way exists to determine whether these negative productivity growth rates fundamentally reflect the sharp output declines that occurred during this period. In addition, we cannot yet measure productivity growth among the nonresidential contractors that match the new PPIs. Therefore, until data for further years become available and until productivity information for actual nonresidential contractors can be collected, no reliably accurate way exists to determine what productivity growth has been among contractors.

53 Using individual industries as the comparison group is more appropriate than using the nonfarm business sector as a whole, because the output concepts are more comparable. It is well known that measures of productivity growth based on value-added concepts, as used within the nonfarm business sector, typically show greater rates of productivity growth than estimates based on gross output.

54 Table 7 of SRMPY 2014 (Sveikauskas et al., “Productivity growth in construction,” Working Paper 478, p. 43), summarizes information on the total hours employed in each industry. Single-family housing employs more hours than the other industries

considered in the present article. Recall that almost all operative builders (now called for-sale builders) are eventually included in single-family housing.

55 However, these same industries represent almost 20 percent of total output in construction because the housing industries account for more of output than of directly employed labor.

56 The relatively low productivity growth in single-family housing and in highways, the two largest of our four industries, suggests that productivity gains in the sum of the four industries could potentially be relatively low. On the other hand, the balance of the evidence clearly shows that productivity growth has been positive, rather than negative or zero.

57 On the basis of a personal conversation with authors, a reader noted that the measure of revenues includes subcontractors and that the corresponding measures of labor input should therefore preferably also reflect subcontractor labor. This point gives added credence to the lower, but still generally positive, estimates of productivity growth that include subcontractor labor. However, the available output price deflators reflect the gross value of a final construction product, rather than builder value added, so we cannot simply remove contractor services from our measures of gross output.

58 Note that table 4 shows data only up to 2015, since 2016 information is not yet available for some of the industries in the comparison group. If labor purchased from other firms, such as subcontractors, is more prevalent in construction than elsewhere, construction may be much less productive than the numbers for direct labor alone may indicate. However, without actual information on labor subcontracting in many industries, we cannot determine how subcontracting affects productivity growth in construction relative to other sectors.

59 We use the terminology “additional portions of construction” here instead of “additional construction industries” because we will not be able to measure productivity growth in any additional complete North American Industry Classification System (NAICS) industries. We will only be able to measure productivity growth in certain portions of a few further NAICS industries.

60 The Producer Price Index for plumbing, except residential, also includes the heating and air conditioning segments of this industry.

61 Since fully reliable information on average weekly hours is available only for North American Industry Classification System (NAICS) industries, we assume that weekly hours are the same throughout all portions of each NAICS industry.

62 Data are accessible at https://www.bls.gov/lpc/construction.htm. For information on more detailed data items, please submit an email to productivity@bls.gov.

63 For more information on the IRS publication, see https://www.irs.gov/statistics/soi-tax-stats-statistics-of-income.

64 See U.S. Census Bureau, “1987 Census of Construction Industries—industry series, highway and street construction contractors except elevated highways” (Washington, DC: U.S. Department of Commerce, January 1990). Additional information can be found at https://www.census.gov/prod/2000pubs/cc92-s-1.pdf.

65 We completed all interpolations using the procedures described in the subsection, “Interpolation between census years.”

66 For information concerning Nonemployer Statistics, go to https://www.census.gov/programs-surveys/nonemployer-statistics/data.html.

67 Once the 1997 to 2016 data have been prepared, P&Ps have to be interpolated further only for the years between 1987 and 1997.

68 For more information on statistic of income bulletin—tax notes, see https://www.taxnotes.com/tax-notes-today/tax-system-administration/irs-announces-fall-2017-statistics-income-bulletin/2017/12/05/1xd0l.

69 Data on the number of partners per partnership are available for nine construction industries in 1997.

70 P&P average weekly hours also could potentially be assigned to industries in proportion to the average hours of construction workers. However, there is no reason to believe that the self-employed or entrepreneurs, who often work long hours, work in the same proportions as production workers.

71 Data on the deflators and on average weekly hours are available for each year and, therefore, do not have to be interpolated. Data on subcontractor labor hours are interpolated between census years on the basis of employment.

72 For more information on "Value of construction put in place," go to the U.S. Census Bureau's website at https://www.census.gov/econ/overview/co0300.html.

73 Sveikauskas et al., "Productivity growth in construction," Working Paper 478, pp. 73–74.

RELATED CONTENT

Related Articles

Employment expansion continues but at a slower pace, *Monthly Labor Review*, April 2017.

Measuring quarterly labor productivity by industry, *Monthly Labor Review*, June 2016.

Construction employment: a visual essay, *Monthly Labor Review*, November 2011.

The U.S. housing bubble and bust: impacts on employment, *Monthly Labor Review*, December 2010.

Related Subjects

Statistical methods | Labor force | Productivity | housing | Construction | industry | Employment | Economic development and growth | Recession