Productivity Growth in Construction

Leo Sveikauskas[1]; Samuel Rowe[2]; James Mildenberger[3]; Jennifer Price[4]; and Arthur Young[5]

Abstract: Measuring productivity growth in construction has been a classic challenge, largely because reliable output deflators are scarce. This paper reports first results from a Bureau of Labor Statistics research group convened to measure construction productivity better. Results show that labor productivity growth has been positive, and fairly substantial, in all four industries where reliable deflators now exist. Shifts of labor between construction industries reduce productivity growth by 0.4% a year. Regulation is a significant negative effect on productivity, but reduces productivity growth by only 0.1% a year. Undocumented immigrants are important in construction, and often work off the books, but reasonable allowance for their increased presence reduces productivity growth by only 0.1% a year. The influences examined are not sufficient to explain why productivity growth is so much lower in construction than elsewhere. Later work will measure productivity growth in a broader range of industries, including some industries representing contractors. However, this further work requires access to restricted Census microdata, and so will take several years more to complete. **DOI: 10.1061/(ASCE)CO.1943-7862.0001138.**

Author keywords: Productivity; Construction industry; Statistics; Regulations; Quantitative methods.

Introduction

In recent years, many observers [such as Rojas and Aramvareekul (2003) or Building Futures Council (2006)] have emphasized the need for improved measures of productivity growth in construction. The Bureau of Labor Statistics (BLS) also published new measures of output prices, within the Producer Price Index (PPI) program, which eliminated one of the main obstacles to more reliable estimates of productivity growth. Because of the strong public interest, and the availability of relevant new information, in 2012 the productivity office of the Bureau convened a research team to improve measures of productivity growth in construction.

The goal of this paper is to present first results from the new research program. Consistent with standard statistical agency terminology, this report refers to construction as a whole as a *sector* and to portions of this sector as *industries*. The analysis prepares reliable measures of productivity growth for four industries in construction where the necessary data are now readily available. The central data on production come from the Census of Construction (U.S. Census Bureau 2012), which is the only source that provides consistent information on output and inputs. Because the census is conducted only once in every 5 years, productivity in the intervening years is interpolated from a variety of alternative sources.

Previous studies often suggested that productivity growth has been negative in construction, both in the United States [Teicholz 2013; L. Sveikauskas, S. Rowe, J. Mildenberger, J. Price, and A. Young, "Productivity growth in construction," working paper 478, Bureau of Labor Statistics, Washington, District of Columbia. (Section I), henceforth called SRMPY (2014)] and internationally (Abdel-Wahab and Vogel 2011). Because high-quality output deflators are so scarce, many previous estimates of productivity growth, in the total construction sector or in individual industries, could potentially be quite inaccurate.

Various reasons have been invoked to explain negative productivity trends, such as industry shifts within construction (Allen 1985), increases in land-use regulation (Ganong and Shoag 2012), and the use of questionable deflators. As Allen (1985) and Pieper (1991) emphasize, in the United States the single-family residential deflator and the Turner Construction Cost Index are often used to approximate output price trends in other segments of construction. Such proxy deflators could be seriously misleading. This study also examines the influence that industry shifts, increases in regulation, and the presence of undocumented immigrants have on observed productivity growth.

Productivity Growth in Four Industries

This section prepares measures of productivity growth for four industries in construction where high-quality deflators and the corresponding output measures already exist. The four industries are single-family housing, multiple-family housing, highways, and industrial construction. To the best of the authors' knowledge, no one has previously studied productivity growth in any of these industries using these deflators. The four crucial deflators come from four different sources. The Census publishes an improved version of the Musgrave (1969) single-family deflator. The Bureau of Economic Analysis (BEA) provides the de Leeuw (1993) multiple-family deflator. The Federal Highway Administration prepares the National Highway Construction Cost Index (NHCCI) for highways. The BLS Producer Price Index includes a deflator for

[1]Research Economist, Office of Productivity and Technology, Bureau of Labor Statistics, 2 Massachusetts Ave. NE, Washington, DC 20212 (corresponding author). E-mail: sveikauskas.leo@bls.gov

[2]Economist, Office of Productivity and Technology, Bureau of Labor Statistics, 2 Massachusetts Ave. NE, Washington, DC 20212. E-mail: rowe.samuel@bls.gov

[3]Economist, Office of Productivity and Technology, Bureau of Labor Statistics, 2 Massachusetts Ave. NE, Washington, DC 20212. E-mail: mildenberger.jim@bls.gov

[4]Economist, Office of Productivity and Technology, Bureau of Labor Statistics, 2 Massachusetts Ave. NE, Washington, DC 20212. E-mail: price.jennifer@bls.gov

[5]Economist (retired), Office of Productivity and Technology, Bureau of Labor Statistics, 2 Massachusetts Ave. NE, Washington, DC 20212. E-mail: a73bluejay@aol.com

Note. This manuscript was submitted on June 15, 2015; approved on December 7, 2015; published online on March 29, 2016. Discussion period open until August 29, 2016; separate discussions must be submitted for individual papers. This paper is part of the ***Journal of Construction Engineering and Management***, © ASCE, ISSN 0733-9364.

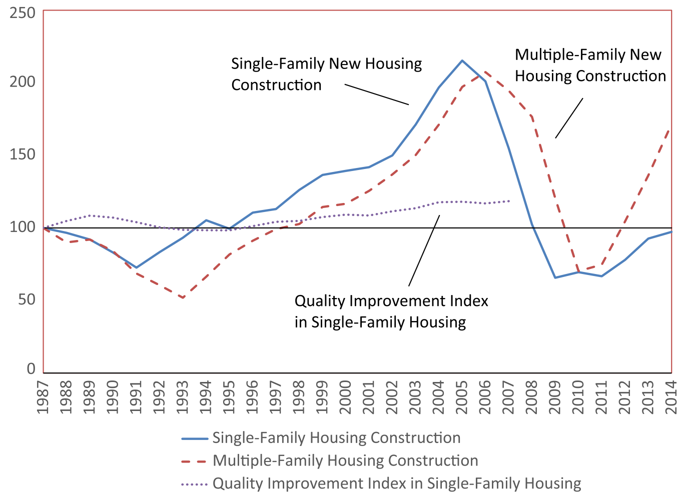

Fig. 1. Output in housing

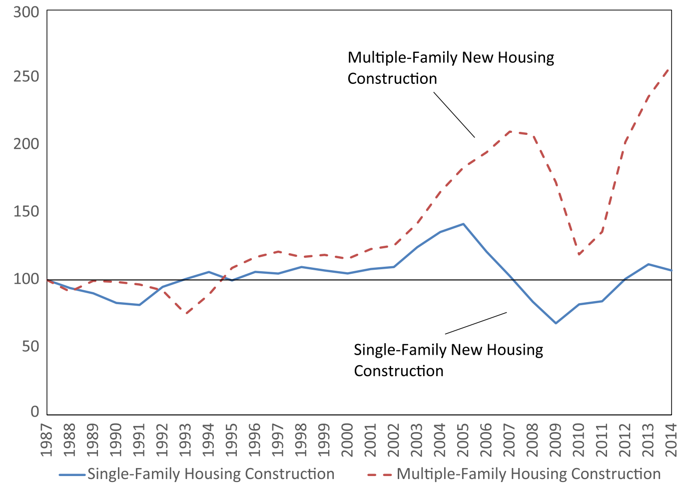

Fig. 3. Labor productivity in housing

industrial construction. The analysis covers single- and multiple-family housing from 1987 to 2014. The other deflators are more recent. Highways begin in 2002 and industrial building in 2006.

Because it is so difficult to measure capital and materials inputs, this study examines only labor productivity growth. The Appendix briefly describes data sources and SRMPY (2014, Appendix A) describes the data in detail. However, the present work extends beyond SRMPY (2014) because information from the 2012 Census of Construction is incorporated here. Sveikauskas et al. (2016), henceforth SRMPY describes how the new measures of industry productivity growth are prepared in clear nontechnical language.

Fig. 1 shows output trends for single- and multiple-family residential construction. Output reaches a sharp peak during the 2004–2007 boom, and then declines rapidly. Multiple-family construction reaches its peak a little later, presumably because projects last longer. Most of the increased output consists of larger numbers of housing starts; the quality improvement index for single-family housing increases only modestly. Fig. 2 reports corresponding information on the growth of labor input in each of the housing industries. Labor inputs increase less rapidly than output, especially in multiple-family housing. Fig. 3 shows that productivity growth is consequently much more rapid in multiple-family housing, but

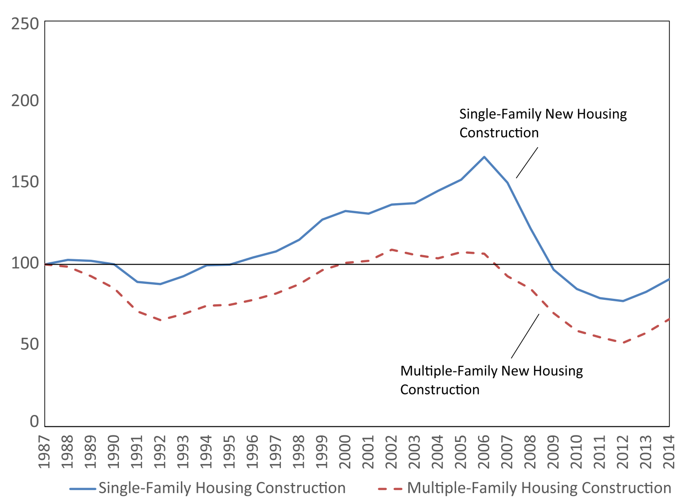

Fig. 2. Labor input in housing

reached a sharp peak in both industries in the 2004–2007 boom period. Productivity falls sharply in the ensuing crash, and then begins to recover after 2010.

Productivity increased slightly in these industries from 1987 to 2003 or 2004, before the onset of the boom, which suggests a mild positive trend in normal times. However, the overall record is dominated by the boom and the ensuing crash. To get a better sense of the longer run trend, consider the regression

$$\log{(O/L)}_{i,j} = \alpha + \beta \log{(\text{Housing Starts})}_{i,j} + \gamma \text{time}_i \qquad (1)$$

in which the number of housing starts controls for cyclical effects; O = gross output; and L = labor input, so that $(O/L)_{i,j}$ = labor productivity in year i in industry j. Eq. (1) is estimated separately for single- and multiple-family housing; single-family housing starts are used in the single-family estimates, and multiple-family starts in the multiple-family analysis. The value of γ provides an estimate of long-term productivity growth.

The first four rows of Table 1 measure labor input as the hours directly employed in each industry. Results are based on Eq. (1) for each of the housing industries from 1987 to 2014. As the coefficients for γ indicate, the estimated time trend is positive for each industry. After controlling for cyclical variation, productivity increased 1.2% a year in single-family housing and 3.8% a year in multiple-family construction.

Table 1. Productivity Growth in Housing, 1987–2014

Type of labor	Variable	Constant	Housing starts	Time	Fit and sample size
Direct labor only	Single family	−21.734	0.417	0.0117	$\bar{r}^2 = 0.82$
	t-ratios	-5.26^a	8.39^a	5.66^a	$n = 28$
	Multiple family	−72.538	0.300	0.0379	$\bar{r}^2 = 0.84$
	t-ratios	-10.09^a	3.32^a	10.65^a	$n = 28$
Direct and indirect labor	Single family	−18.915	0.291	0.0107	$\bar{r}^2 = 0.48$
	t-ratios	-2.81^a	3.93^a	3.18^a	$n = 28$
	Multiple family	−27.579	0.198	0.0156	$\bar{r}^2 = 0.43$
	t-ratios	-2.73^b	1.75	3.15^a	$n = 28$

Note: Regressions based on Eq. (1). Standard errors and t-ratios reflect the Newey–West (1987) correction for autocorrelation. Results are based on a 1-year lag in the error term; similar patterns appear for two-year lags.
[a]Significantly different from zero at the 99% level.
[b]Significantly different from zero at the 95% level.

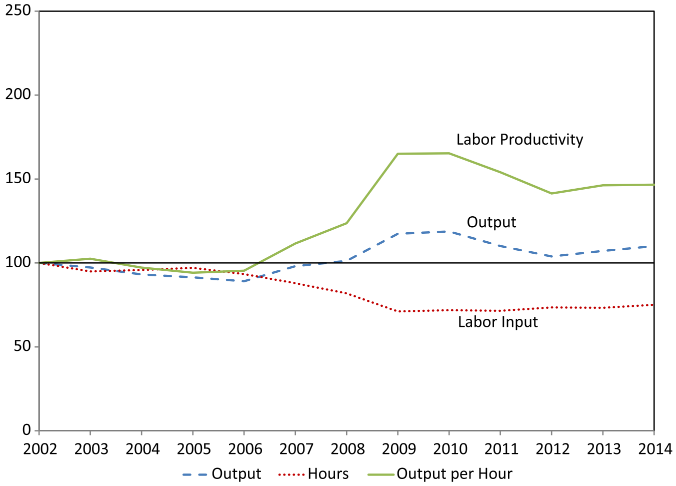

Fig. 4. Productivity in highways

Figs. 4 and 5 describe output, labor, and productivity growth in the construction of highways, streets, and bridges from 2002 to 2014 and the construction of industrial buildings from 2006 to 2014. In both cases, the productivity trend is clearly positive. Cyclical variation is much less extreme in these two industries. Using average annual rates of growth over the entire period, productivity increased 3.2% a year in highways and 2.3% a year in industrial construction.

Subcontractor Labor

Many builders use subcontractor labor, often supplied by specialists such as plumbers or carpenters, to supplement or replace their own labor force. The services of subcontractors would normally be included as materials inputs; because it is not possible to include materials inputs, the analysis instead measures the subcontractor labor indirectly supplied to each industry, and treats labor provided by subcontractors as a supplementary labor input.

The Census of Construction reports how much output contractors in each field (such as plumbers or electricians) deliver to each type of construction (such as single- or multiple-family residential construction). In addition, the census shows how much output is delivered to each type of construction for new construction; for additions, alterations, and renovations; and for maintenance and repair.

To determine how much labor subcontractors provide to builders in the residential industries, assume that subcontractor deliveries (of output) for additions and alterations are twice as labor intensive (have twice the labor:output ratio) as deliveries for new construction. Similarly, assume that output delivered for maintenance and repair is three 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 valid over time. Sveikauskas et al. (2016) explains why labor:output ratios of 1, 2, and 3 are selected.

Given these assumptions, it is possible to determine how much of the labor supplied by a particular type of contractor, perhaps carpenters, is allocated to each different facet of production. Assume, for example, that carpenters supply 60% of their *total output* (deliveries to all sectors, not just to home building) to new construction, 20% to additions and alterations, and another 20% to maintenance and repair. In conjunction with the labor:output ratios of 1, 2, and 3

$$0.60 \cdot 1x + 0.20 \cdot 2x + 0.20 \cdot 3x = L \tag{2}$$

where L = total labor input employed by the carpenters.

Solving Eq. (2) for x, $x = L/1.60$, so the total labor carpenters supply to new construction is $0.60/1.60\ L$, and 0.375 of all carpenter subcontractor labor is delivered to new construction. Once the amount of labor delivered to new construction has been determined, this can in turn be allocated to specific industries. For example, if 80% of carpenter output delivered to new construction is supplied to single-family home building, 0.80×0.375, or 30%, of all carpenter contractor labor is supplied indirectly to single-family home building. Once the labor that carpenters, plumbers, roofers, 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 indirect labor input. An entire set of such calculations is performed separately for each census year.

The last four rows of Table 1 show that even with this expanded definition of labor input, long-term productivity growth is still positive. Labor productivity growth is 1.1% a year in single-family housing and 1.6% in multiple-family construction. Similarly, when subcontractor labor is included, long-term productivity growth is 0.5% in highways and 2.7% in industrial construction. Figs. 6 and 7 illustrate productivity growth in each of the four industries

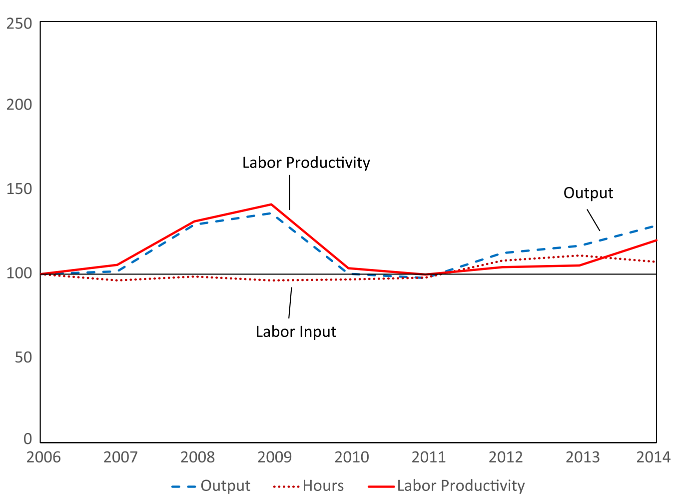

Fig. 5. Productivity in industrial construction

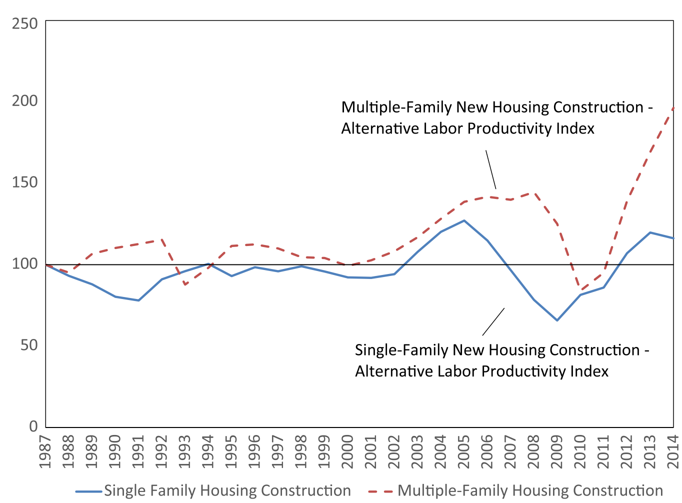

Fig. 6. Productivity growth, housing (includes indirect labor)

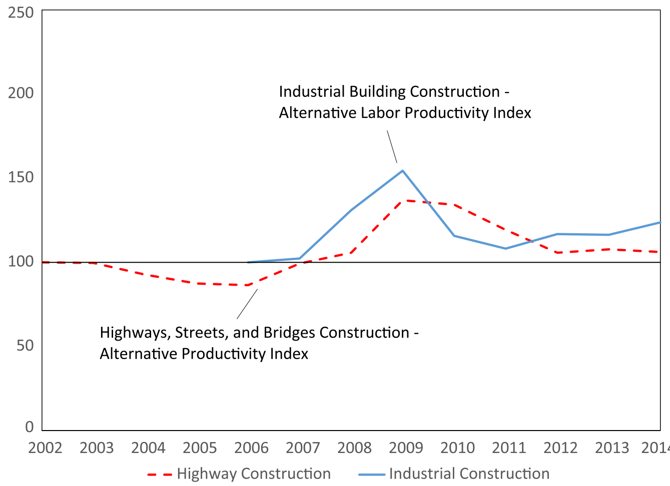

Fig. 7. Productivity growth, highways, and industrial construction (includes indirect labor)

using the more comprehensive measure of labor input. SRMPY (2014, Section IIC) briefly considers how results differ for alternative assumptions concerning labor input requirements. For example, input requirements of one, two, and five do not appreciably change the results.

This evidence shows that long-term labor productivity growth is positive and fairly substantial in each of the four industries considered. These patterns indicate that productivity has been positive in some portions of construction. The four industries considered here represented 19.4% of output and 10.6% of direct labor input in construction in 2012, so the available evidence already covers a worthwhile share of construction. Measures for further industries will eventually provide a somewhat more complete picture.

Shifts among Industries

Allen (1985) examined the role of industry shifts using data on receipts for single-family homes, office and industrial buildings, and educational and hospital buildings. Allen concluded that, between 1968 and 1978, labor productivity growth was negative in the overall construction sector in part because low-productivity portions of the sector were growing more rapidly. His evidence (p. 665) showed that industry shifts reduced productivity by 4.5% over the decade, which translates to approximately 0.44% per year. Allen examined the role of industry shifts using data on receipts for single-family homes, office and industrial buildings, and educational and hospital buildings.

This study concentrates on shifts of labor between industries. There are two reasons to concentrate on labor input. First, output cannot be measured accurately over time simply because good deflators do not exist. Information on receipts combines output growth and price changes in unknown proportions, and is therefore difficult to interpret. Second, it is useful to consider shifts between all 31 North American Industrial Classification System (NAICS) industries in construction, not just the three major groups examined by Allen. This section, therefore, measures industry shifts instead by the industry distribution of labor input.

To understand the impact of labor shifts on aggregate productivity, consider the identity

$$\bar{O/L} \equiv \sum_{i=1}^{31} shl_i (O/L)_i \qquad (3)$$

in which labor productivity over all NAICS construction industries, $\bar{O/L}$, is the sum of labor productivity in each of the 31 industries, $(O/L)_i$, weighted by the share of overall labor input, shl_i, observed in each industry *i*. In order to understand the likely impact of shifts in labor inputs, this section first calculates the relationship in Eq. (3) for 1987 using 1987 labor input weights for each industry. The next step then examines what 1987 productivity would have been if 2012 labor input weights were used instead. The difference shows how much lower productivity would have been in 1987 solely because of the labor input shifts observed by 2012. Such estimates provide a rough indication of productivity losses due to the shift in the distribution of labor hours observed between 1987 and 2012.

Table 2 reports the share of hours in each industry in 1987, 2007, and 2012 and labor productivity, O/L, for each industry in 1987. Between 1987 and 2012, labor shifted modestly from the construction of buildings and heavy construction, and increased correspondingly among contractors. The share of labor in new housing construction declined substantially between 2007 and 2012.

Table 3 presents empirical results from Eq. (3). Between 1987 and 2012, industry shifts reduced output by 0.41% per year. This is a substantial impact, although a little less than Allen's estimate of 0.44% per year from 1968 to 1978.

Bias Associated with Less Reliable Deflators

For many years, the BEA used the single-family or Turner Construction Cost Index to deflate output in many portions of construction where no more specific deflators were available. Such proxy deflators may introduce serious errors into measures of construction output.

Between 2005 and 2007, BLS introduced new PPIs for warehouses, schools, offices, and industrial buildings. Harper (2014) provides a detailed description of the methods used to prepare these new PPIs for construction. The new PPIs represent a clear improvement over the single-family or Turner index because (1) they are industry specific rather than using data from another industry as a proxy index, and (2) they do not use a cost index as a weighted portion of the final index. The BEA, therefore, adopted the new PPIs to deflate the corresponding types of structure in the national income and product accounts.

How do the new more accurate PPI deflators compare with the less accurate approximations used in prior years? Such comparisons can help analysts understand how reliable construction deflators were during the many long years when the single-family or Turner index was used to deflate many types of construction. Table 4 presents evidence on this question. The first four lines of Table 4 examines price growth from the first quarter in which each new PPI was available until the fourth quarter of 2012. Once the new PPIs were adopted, they each grew at least 2% *more rapidly* than the old unreliable deflators.

SRMPY (2014, Section IIIB) interpreted such evidence as indicating that the PPIs generally increase *faster* than the single-family or Turner deflator. A more rapid rate of price increases implies a smaller growth in deflated output, and therefore *slower* productivity growth in construction. Because of the importance of this issue, it is worthwhile to reexamine the PPI and old deflators in data after the fourth quarter of 2012. The last four lines of Table 4 shows that in 2013 and 2014, the PPIs increased approximately 3 percentage points *slower* than the single-family or Turner index. Such patterns suggest *faster* growth of construction output. The old deflator, which includes the single-family residential deflator

J. Constr. Eng. Manage., 2016, 142(10): 04016045

Table 2. Industries Included in the Labor Shift Analysis, Shares of Hours, and Output per Hour in 1987

Industries in construction		Shares of hours			
NAICS	Title	1987 (%)	2007 (%)	2012 (%)	O/H
236115	New single-family housing construction (except operative builders)	4.2	4.4	3.1	59
236116	New multiple-family housing construction (except operative builders)	0.8	0.5	0.3	110
236117	New housing operative builders	3.5	3.1	1.7	129
236118	Residential remodelers	5.3	5.5	7.4	45
236210	Industrial building construction	1.8	0.8	1.1	58
236220	Commercial and institutional building construction	9.6	7.0	7.2	96
237110	Water and sewer line and related structures construction	2.5	2.1	2.2	51
237120	Oil and gas pipeline and related structures construction	1.3	2.0	2.9	29
237130	Power and communication line and related structures construction	2.1	2.2	3.3	37
237210	Land subdivision	1.1	1.3	0.4	191
237310	Highway, street, and bridge construction	5.9	4.2	4.3	58
237990	Other heavy and civil engineering construction	2.0	1.0	1.4	52
238110	Poured concrete foundation and structure contractors	2.9	3.9	3.0	35
238120	Structural steel and precast concrete contractors	1.0	1.0	0.9	45
238130	Framing contractors	2.4	2.1	1.2	24
238140	Masonry contractors	3.6	2.9	2.2	26
238150	Glass and glazing contractors	0.9	0.7	0.6	41
238160	Roofing contractors	3.2	2.2	2.4	35
238170	Siding contractors	0.8	0.8	0.7	30
238190	Other foundation, structure, and building exterior contractors	0.4	0.6	0.7	36
238210	Electrical contractors and other wiring installation contractors	9.1	9.8	10.5	36
238220	Plumbing, heating, and air-conditioning contractors	10.6	11.2	12.2	42
238290	Other building equipment contractors	1.5	1.7	1.9	45
238310	Drywall and insulation contractors	3.8	4.1	3.4	39
238320	Painting and wall covering contractors	5.0	4.8	4.7	19
238330	Flooring contractors	1.7	1.7	1.7	28
238340	Tile and terrazzo contractors	0.7	1.4	1.1	32
238350	Finish carpentry contractors	4.4	3.7	3.3	20
238390	Other building finishing contractors	0.6	0.8	0.9	33
238910	Site preparation contractors	4.2	8.1	7.6	38
238990	All other specialty trade contractors	3.2	4.5	5.4	32
23	Construction	100	100	100	50

Note: Shares of hours represent the proportion of total construction hours observed in each industry. Hours include partners and proprietors. O/H measures dollars per hour in 1987.

Table 3. Index of Output due to Shifts in Hours, 1987–2012, 1987 = 100.00

Year	Output in 1987 using shares of hours for that year
1987	100.00
1992	98.31
1997	96.84
2002	96.29
2007	95.02
2012	90.18
Average annual rate of change	−0.41%

Note: Estimates from Eq. (3) using 1987 values of O/L and shares of hours in each of the 31 industries. Hours include partners and proprietors.

with weight 1/2, may have declined unusually sharply from 2005 to 2012 because of the housing crash that occurred during these years. In more normal times, such as in the housing recovery of 2013 and 2014, the improved PPIs probably increase less than the traditional deflator. However, it will be necessary to follow these data carefully in future quarters to determine whether the PPIs typically increase more slowly during normal times.

Regulation

Many regulations are binding on a state or a local level. Because measures of the value added of construction output are available on

Table 4. Construction Output Prices from the New PPIs Compared with Their Predecessors, 2005–2012, and 2012 Fourth Quarter to 2014 Fourth Quarter

Time period	Type of construction	Period of coverage	PPI growth (%)	Old deflator growth (%)	Growth difference (%)
2005–2012	Warehouse construction	2005 first quarter to 2012 fourth quarter	3.47	1.61	1.87
	Educational construction	2006 first quarter to 2012 fourth quarter	4.47	0.51	3.96
	Office construction	2006 third quarter to 2012 fourth quarter	2.32	0.07	2.25
	Industrial construction	2006 third quarter to 2012 fourth quarter	2.28	0.07	2.21
2012 fourth quarter to 2014 fourth quarter	Warehouse construction	2012 fourth quarter to 2014 fourth quarter	2.57	5.90	−3.33
	Educational construction	2012 fourth quarter to 2014 fourth quarter	2.75	5.90	−3.15
	Office construction	2012 fourth quarter to 2014 fourth quarter	2.49	5.90	−3.41
	Industrial construction	2012 fourth quarter to 2014 fourth quarter	3.02	5.90	−2.88

Note: The same old deflator (1/2 the single-family residential construction index and 1/2 the Turner Construction Cost Index) is used for each of the four types of buildings. The old deflator reported in the fifth column for the 2005–2012 time period takes on different values for each type of construction only because the time periods differ.

Table 5. Estimates of the Effect of Regulation on Productivity Growth When the Impact of the Growth of Regulation Is Weighted by the Regulation Share; in Each Specification the Dependent Variable Is $\log\,(V/L)_{i,t} - \log(V/L)_{i,t-1}$

Coefficients or t-ratios	Difference in log regulation	Weighted difference in log regulation	State dummies	Time dummies	Time trend	Observations	R^2	Standard error of the estimate
Coefficient	−0.0226	—	No	Yes	No	1,584	0.50	0.03
t-ratio	−1.24	—	—	—	—	—	—	—
Coefficient	—	−7.4884	No	Yes	No	1,584	0.50	0.03
t-ratio	—	−2.18	—	—	—	—	—	—
Coefficient	0.006	−8.2352	No	Yes	No	1,584	0.50	0.03
t-ratio	0.25	−1.80	—	—	—	—	—	—

Note: Difference in log regulation is $\log\,(\mathrm{Reg})_{i,t} - \log(\mathrm{Reg})_{i,t-1}$; weighted difference in log regulation is $[\log(\mathrm{Reg})_{i,t} - \log(\mathrm{Reg})_{i,t-1}] \times \mathrm{Reg}_{i,t-1}$; regressions based on Eqs. (5) and (7).

a state level, this section analyzes the impact of regulation within state data. Ganong and Shoag (2012) developed an index of land-use regulation in each state in each year. Their measure consists of the proportion of appellate cases in each state that use the phrase *land use*. This measure is cumulative in the sense that the total number of references to land use and the number of cases are updated each year; however, if new cases refer to land use less often, the cumulative measure can decline. Because an index of land-use restriction based on legal practice might appear to be unconnected from actual building practice, it is important to note that Ganong and Shoag show that their measure of land-use limits is correlated with prior measures of actual land-use restriction in different geographic areas.

The Ganong–Shoag measure appears to be a reasonable fit for construction. Land-use law in all its ramifications limits housing development, office and store development, and many other forms of construction. The empirical work examines the effect of regulation on productivity in several different ways in order to obtain an overall impression of the magnitude and consistency of implied effects. First, examine a relationship in levels. Specifically

$$\log\,(V/L)_{i,t} = a + \beta \log\,(\mathrm{Reg})_{i,t} \tag{4}$$

where $(V/L)_{i,t}$ = value added per unit of labor in state i in year t; and $(\mathrm{Reg})_{i,t}$ = cumulative amount of regulations binding in each observation, as measured by the Ganong–Shoag index. Eq. (4) is expressed in terms of real value added, $V_{i,t}$, rather than gross output, $O_{i,t}$, because BEA publishes data on only value added (gross product originating) for the construction industry in each state. Eq. (4) can be expressed alternatively in first difference form as

$$\log\,(V/L)_{i,t} - \log\,(V/L)_{i,t-1} = \beta[\log\,(\mathrm{Reg})_{i,t} - \log(\mathrm{Reg})_{i,t-1}] \tag{5}$$

In both versions, the central hypothesis is that the presence of regulations has a negative effect on observed productivity, so that the estimate of β, $\hat{\beta}$, is expected to be negative.

Finally, the literature on economic growth generally describes how much any factor contributes to growth by weighting that factor's observed growth rate by its relative importance. For example, the same percentage increase in regulation will hold back productivity growth more strongly if the share of regulation is high. Specifically

$$\log\,(V/L)_{i,t} - \log\,(V/L)_{i,t-1} = a_{\mathrm{REG}}[\log\,(\mathrm{Reg})_{i,t} - \log\,(\mathrm{Reg})_{i,t-1}] \tag{6}$$

where a_{REG} = regulatory costs as a share of output. Eq. (6) permits increases in regulation to have a greater impact when α_{REG} is high.

No specific information is available on α_{REG}, regulatory costs as a share of output. However, information on the proportion of appellate cases that mention land-use regulation does exist. Assume that the share of cases that mention regulation in each state i in year t provides information on the cost share of regulation in that observation. Then

$$\log\,(V/L)_{i,t} - \log\,(V/L)_{i,t-1} = \hat{\beta}^{*}\alpha_{\mathrm{CASES}\,i,t-1}[\log\,(\mathrm{Reg})_{i,t} - \log\,(\mathrm{Reg})_{i,t-1}] \tag{7}$$

where $\hat{\beta}^{*}$ = regression estimate from Eq. (7). The regression estimate $\hat{\beta}^{*}$ multiplied by the average proportion of cases that mention land use, $\alpha_{\mathrm{CASES}\,i,t-1}$, can then provide an estimate of a_{REG}, the share of regulation in total costs of construction. SRMPY (2014, p. 50) shows that the implications for productivity growth are similar if the cost share of regulation is more generally permitted to be a linear function of the proportion of cases.

Empirical estimates from Eqs. (4) and (5) suggest that $\hat{\beta}$ is approximately −0.03. A doubling of regulation is associated with approximately a 3% decline in productivity. In 2010, Reg was 0.00077 in Alabama and 0.03389 in Maine. Reg doubles more than five times over this range, which implies a productivity decline of more than 15%. SRMPY (2014) calculates the productivity decline associated with increased regulation in every state over this period, and concludes that the overall productivity loss is only 0.1%. Table 5 shows that the data prefer Eq. (6) to Eqs. (4) or (5), which is not surprising given the theoretical preference for the share-weighted Eq. (6). The preferred estimate for $\hat{\beta}^{*}$, from Table 5, is −7.488, which, because the average value of $\alpha_{\mathrm{CASES}\,i,t-1}$ throughout the sample is 0.005, implies a factor share of (−7.488 × 0.005), or −0.037%. That is, in the total sample, regulatory costs amount to 3.7% of the value added in construction. (The 3.7% cost share is tentative, however, because alternative assumptions can lead to different results.) Of course, such estimates do not address the benefits typically associated with regulation. Finally, Eq. (6) once again implies that increases in regulation reduce productivity growth by 0.1% a year. SRMPY (2014, Section VA) provides much more information and detail concerning how the effects of regulation are calculated.

Labor Input of Undocumented Immigrants

Passel (2006) showed that undocumented immigrants are much more likely to work in construction than in most other industries. If considerable numbers of undocumented immigrants work off the books, they may not be included in existing measures of labor input.

To prepare ballpark estimates of how much the omission of some undocumented immigrants affects measures of productivity growth in construction, begin with Passel and Cohn's (2011) estimates of the absolute number of undocumented immigrants and the proportion of the population they represent. SRMPY (2014, Section VB) uses these data to extend estimates of undocumented immigrants as a share of the population to further years, and converts population shares to labor force shares.

The next step is to determine how much of the unauthorized immigrant labor force is employed in construction. Passel (2006, p. 14) notes that in 2005, undocumented workers were 12% of all workers in construction, but represented only 4.9% of all workers. Assume that each 1% of the work force, who are undocumented immigrants, leads to 12/4.9 or 2.45% representation of undocumented immigrants in the construction work force. Such a conversion factor converts the existing measures of the proportion of immigrants in the labor force into the equivalent representation in the construction work force. SRMPY (2014, p. 59) suggests that such calculations probably overstate the true long-term increase in immigrant labor.

Once the implied number of undocumented immigrants working in construction is known, this information can be combined with the data on the total number of hours worked in construction from 1987 to 2011 developed previously. The data suggest that immigrant hours grew at an 8.38% annual rate over this period, whereas native hours increased by 0.26% per year. However, even by 2011, immigrants still remained a fairly small share (12.8%) of overall labor input.

The data previously show that labor hours in construction grew 0.74% a year between 1987 and 2011. If the Pew Research Center (2013) is correct in estimating that 15% of undocumented immigrants are off the books, beyond existing data, then immigrant labor increases more rapidly than the data show, but the unmeasured increment is only sufficient to increase labor input to 0.81% per year, implying a 0.07% decrease in productivity growth. If 30% of undocumented immigrants are off the books, this would increase true labor input growth to 0.87% per year, implying a 0.13% decline in labor productivity growth. Even if 50% of undocumented workers were off the books, productivity growth would be overstated by only 0.22% a year. The implied effects on productivity growth are not immense; the undocumented immigrant share of the work force is still sufficiently small that an understatement of the growth of undocumented immigrant labor does not greatly alter understanding of productivity growth in total construction. SRMPY (2014, Section VB) provides much more detailed information showing exactly how these estimates of the effect of unauthorized immigrants are prepared.

Conclusions

One of the main points of tension in the literature is that the available estimates show construction productivity has declined for half a century, but many observers doubt that such prolonged declines have actually occurred. This study developed reliable measures of productivity growth in four industries; all four of these estimates show clear and substantial productivity growth. These positive trends still occur if labor obtained from subcontractors is also included. Such results shift the debate toward the notion that productivity growth has been positive. However, the data do not yet include industries representing contractors and other observations in which additions or alterations and maintenance or repair are important. Productivity growth may be much more limited in these other portions of construction. It is therefore too early to conclude that productivity growth has definitively been positive in overall construction.

Some additional influences do reduce productivity growth. Shifts of labor toward lower-productivity industries reduce productivity growth by a substantial 0.4% a year. Increases in regulation have a statistically significant negative effect, but reduce productivity growth by only 0.1% annually. The increased prevalence of undocumented immigrants implies that observed productivity growth is overstated by approximately 0.1% a year. Nevertheless, all these influences together cannot explain why productivity growth has been so much lower in construction than in the rest of the economy.

Future work will expand the analysis to use confidential (establishment level) microdata available at the U.S. Census Bureau. The microdata will make it possible to understand production in at least seven other industries. The new industries include warehouses, schools, offices, and several contractor industries; this added information will make it possible to describe production in a broader range of construction industries. The much greater detail available in the microeconomic data may also make it possible to prepare estimates of capital and materials inputs and, thereby, of multifactor productivity growth. However, access to the confidential microdata requires careful review from the relevant government agencies, which takes considerable time. In addition, the team will have to examine the new information carefully, cleanse any data imperfections, and conduct the necessary analyses. Consequently, it will take at least several more years before work can be expanded to include these additional industries.

Appendix. Data Sources

The fundamental data are obtained from the Census of Construction because the census is the only source that provides consistent information on output and inputs. Output is the value of construction work deflated by the appropriate deflator, and also contains nonconstruction work performed by establishments classified in each industry. The output price deflators are described in the text; standard deflators and methods are used to price output of products secondary to each industry. Labor input is obtained from Census of Construction data on construction and nonconstruction workers, supplemented by information on average weekly hours of workers based on the Bureau of Labor Statistics Current Employment Statistics. Labor inputs always include the partners and proprietors in each industry. Data from Internal Revenue Service publications are used to measure the number of partners in each partnership in construction. Average weekly hours of partners and proprietors in construction are obtained from the Current Population Survey.

Because the Census of Construction provides information only for census years, data for the intervening years are obtained through interpolation. Output is interpolated using data from the census report on the Value of Construction Put into Place (U.S. Census Bureau 2016). Employment is allocated in proportion to annual data from the BLS Current Employment Statistics. SRMPY (2014, Appendix A) provides much more detailed information on data sources, methods of measurement, and procedures for interpolation. Production in NAICS 236117, for-sale builders, is assigned to single- and multiple-family construction on the basis of industry detail published in the 2007 census. Approximately 98% of output and employment in NAICS 236117 is allocated to single-family residential construction.

Acknowledgments

The authors comprise the Productivity Growth in Construction team at the Bureau of Labor Statistics. We appreciate comments from participants at the 2013 BLS-Census Joint Research Conference and at the 2013 National Bureau of Economic Research Summer Institute. We thank Lisa Usher, former chief of the Division of Industry Productivity Studies at the BLS, for continuing support, and many readers associated with the construction sector for their helpful comments. We are grateful to Paul Teicholz for many detailed discussions which have greatly improved our work. We also thank Peter Ganong and Daniel Shoag for generously sharing their data on land-use regulation. Of course, the authors are solely responsible for any errors or limitations which still remain.

Notation

The following symbols are used in this paper:

Housing Starts = number of housing starts;
L = labor input;
O = gross output;
O/L = labor productivity;
$\underline{O}/L$ = labor productivity in total construction;
shl = labor in a particularly industry as a share of labor in construction;
t = time trend, annually;
V = value added;
α = regression coefficient;
α_{CASES} = proportion of cases using the phrase *land use*;
α_{REG} = implied cost share of regulation in value added;
β = regression coefficient;
$\hat{\beta}$ = regression estimate of β in Eqs. (4) or (5);
$\hat{\beta}^*$ = regression estimate of β in Eq. (7); and
γ = regression coefficient.

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J. Constr. Eng. Manage., 2016, 142(10): 04016045