Productivity Growth in Construction

Leo Sveikauskas, Samuel Rowe, James Mildenberger, Jennifer Price, and Arthur Young

ABSTRACT

Measuring productivity growth in construction is especially difficult both because of the nature of production in the industry and because of the limitations of available data. In particular, price indexes to deflate output are a major problem, since reliable deflators are sparse and the available data suggest productivity has declined for many decades, which is somewhat difficult to believe.

This paper first reviews Bureau of Labor Statistics estimates of productivity growth in the overall construction sector. Second, we develop measures of labor productivity growth in three industries in the construction sector. We examine three industries where reliable deflators exist, single family and multiple family residential construction from 1987 to 2011, and the highways, streets, and bridges industry from 2002 to 2011. These data, which currently cover almost a quarter of construction output, show no sign of any sustained productivity decline. Productivity in residential construction does decline sharply after the housing crash, but the evidence indicates that productivity in residential construction will recover as housing starts return to more normal levels. Furthermore, there is little evidence that long-term productivity growth was negative before the boom.

Third, we analyze labor shifts among 31 industries in construction. Previous work (Allen (1985)) has shown that, from 1968 to 1978, shifts from high to low productivity sectors reduced productivity in construction about 0.44 percent a year. Our results are somewhat smaller, but show that labor shifts still bring about a considerable decline in productivity. Over the last two decades, shifts across industries reduced productivity by approximately 0.25 percent a year. However, most of the productivity decline, especially between 1997 and 2007, still remains to be explained. Finally, we present evidence that regulation of land use, measured in each state in each year, has a small but statistically significant negative effect on productivity growth in construction. In addition, we estimate that the regulation share, the amount by which regulation increased construction costs, was 5.7 percent. Although work on this topic is continuing, we estimate, however, that increases in regulation reduced productivity growth in construction by only 0.1 percent a year.

Productivity Growth in Construction

Leo Sveikauskas, Samuel Rowe, James Mildenberger, Jennifer Price, and Arthur Young[1]

The problem of measuring productivity growth in construction has been an important issue for many years. There are many challenges to measuring productivity in construction, due to the nature of the industry and the limitations of existing data, but two issues stand out. First, there are few reliable output deflators for construction. Second, existing estimates of labor productivity or multifactor productivity growth in construction suggest that productivity has been declining for many decades, which is difficult to believe.[2] This paper reports some progress on these problems, which have been intractable for many years.[3]

There are three main potential reasons why productivity trends in United States construction have been negative for so long. First, there may be some systematic error in the methods United States statistical agencies use to calculate and prepare productivity trends in construction. Second, as Allen (1985) suggested in an influential article, resources may systematically have shifted towards lower productivity portions of the construction industry. Third, productivity growth may have been negative in construction partially because of an increase in environmental regulation which holds back productivity growth in this industry.

Abdel-Wahab and Vogl (2011) recently showed that, in the construction data contained in the Euro-KLEMS data base, both labor and multifactor productivity have declined in most countries. These findings suggest that declining construction productivity is a real problem in many countries; such findings are consequently much less likely to reflect inappropriate measurement within a single statistical system. This paper therefore concentrates primarily on interindustry shifts and regulation as potential explanations for negative productivity trends.

Section I first summarizes the Bureau of Labor Statistics data on productivity change in U.S. construction that indicate negative trends in this sector. A major limitation of these data is that the available output deflators are questionable for many elements of construction, so that measures of

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[1] The authors comprise the Productivity Growth in Construction team at the Bureau of Labor Statistics. At this stage of the process, all material in this paper represents the opinions of the authors, not the views of the Bureau of Labor Statistics. Please do not quote or cite this early version. Comments and suggestions would be very much appreciated; please send any such to Sveikauskas.Leo@bls.gov.

[2] Important references include Stokes (1981), Allen (1985; 1989), Schriver and Bowlby (1985), and Pieper (1989). Dacy (1965) and Gordon (1968) are somewhat earlier contributions. Rojas and Aramvareekul (2003) and Abdel-Wahab and Vogl (2011) are more recent studies published in construction journals.

[3] Pieper (1991) provides a detailed history and evaluation of methods of measuring price deflators in construction.

output and productivity change derived from such deflators are not reliable.[4] On the other hand, measures of capital deepening or materials deepening, which do not reflect the suspect output deflators, are relatively more reliable. Therefore, Section I also considers the influence of capital and materials deepening in construction.

Because the available data on productivity growth in the aggregate construction sector do not explain trends very well, we also search for more detailed information for particular construction industries. Section II considers long-term data on productivity growth in several industries in residential construction and in highway construction, portions of the construction sector in which some adequate output deflators are available for considerable periods of time.

Section III examines Allen's influential hypothesis that construction labor shifts from high to lower productivity industries are an important part of the productivity decline in construction. We confirm Allen's findings for more recent years, although labor shifts are somewhat less important in our data, especially since 1997. Section IV develops measures of productivity growth for each of the 48 mainland states of the United States and tests whether the Ganong-Shoag (2012) measures of land use regulation, which can plausibly be expected to affect all forms of construction, can help to explain the observed negative productivity trends. The results indicate that increases in regulation do reduce productivity growth, but that regulatory restrictions explain relatively little of the observed decline in construction productivity. Section V concludes.

I. Background.

As part of its attempts to measure productivity growth in the aggregate economy, the Bureau of Labor Statistics has prepared unofficial measures of multifactor productivity for a number of sectors and industries outside manufacturing. The productivity series for the construction sector are part of this data set.

Harper, Khandrika, Kinoshita, and Rosenthal (2010) (henceforth HKKR) describe BLS productivity measures for industries outside manufacturing. HKKR include a detailed description of the methods and data used in creating these measures. Their article also presents estimates of productivity growth between 1987 and 2006 in each industry. HKKR also mention earlier BLS efforts to measure productivity growth in these same industries (Gullickson and Harper (1999)). This section draws upon the 1987-2010 data described by HKKR and the 1947-1987 data discussed in Gullickson and Harper (1999). Though the measures differ somewhat, as described in HKKR, both series present broadly consistent measures of aggregate productivity growth in construction.

Each of these data sets is prepared by standard growth accounting procedures. That is, multifactor productivity growth, $\dot{A}/A$, is determined from the relationship:

[4] It is difficult to prepare deflators for construction because the characteristics of each building and the topography of the land vary so widely among projects, so that it is exceptionally challenging to compare the effectiveness of production in different contexts.

$$\dot{O}/O \;=\; \dot{A}/A \;+\; \alpha_K \dot{K}/K \;+\; \alpha_L \dot{L}/L + \; \alpha_M \dot{M}/M \qquad (1)$$

where O is output, K is capital input, L labor input, and M materials input. α_K, α_L, and α_M are the respective cost shares and $\dot{A}/A$ is the multifactor residual, the measure of productivity growth.[5] Equation (1) is often rewritten in terms of labor productivity growth as:

$$\dot{O}/O - \dot{L}/L \;=\; \dot{A}/A \;+\; \alpha_K\big(\dot{K}/K - \dot{L}/L\big) + \alpha_M(\dot{M}/M - \dot{L}/L) \qquad (2)$$

Note that, even if measures of $\dot{O}/O$ and $\dot{A}/A$ are unreliable because of uncertain deflators, the two latter terms of equation (2) still provide useful information on the effects of capital and materials deepening.

Table 1 summarizes the growth of each element of equation (2) for each of the periods 1958-1967, 1967-1977, 1977-1987, 1987-1997, and 1997-2010, as drawn from the unpublished BLS data described in HKKR (2010). First, both labor productivity and multifactor productivity have been negative since 1967. Productivity growth was negative from 1967 to 1987, close to zero from 1987 to 1997, but has been substantially negative since then. Second, since 1987 labor productivity and multifactor productivity trends have been similar, so that labor productivity growth provides a reasonable approximation of multiple factor productivity growth. Third, the capital share (α_K) is consistently quite small, ranging from .033 to .082 in the annual data for the period in concern. Consequently, even rather substantial changes or measurement error in the series on capital services will have relatively little impact on the implied measures of multifactor productivity growth. Since information on capital input is very sparse in detailed industry or state data, the fact that MFP is not very sensitive to capital input is quite helpful.[6] Fourth, the materials share (α_M) is consistently quite high, in the range of .484 to .576. With such a high materials share, materials deepening is potentially a strong influence on labor productivity growth. However, in practice, materials grow at approximately the same rate as labor input, so that materials deepening has had relatively little impact on labor productivity growth.

Information on the effect of capital deepening or materials deepening in construction is quite helpful. The Major Sector Productivity group of the Bureau of Labor Statistics now provides such series on a regular basis which avoids the need to rely on external sources of data to understand the effect of capital deepening.[7] However, the main impediment to better construction productivity numbers is still the lack of suitable output deflators. Section II below therefore turns to estimates of productivity growth based on better output price deflators.

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[5] Throughout this paper, materials inputs include energy and purchased business services.

[6] The capital share is so small that fairly considerable errors in the measurement of capital input will still have relatively little impact on the implied rate of multifactor productivity growth.

[7] Allen (1989) and Pieper (1989) disagreed on which external measure of capital input, obtained from sources outside the BLS, provided the best indicator of capital deepening in construction. Since the BLS data on productivity growth in industries outside manufacturing now provide explicit information on capital, labor, and materials in construction, external information on these items is no longer necessary.

II. Productivity Growth in Residential Construction and in Highways.

This section prepares measures of labor productivity growth for three industries, in residential construction and in highways, where reasonable output price deflators already exist. The measures describe productivity growth in two industries in residential construction from 1987 to 2011, and also cover highway construction from 2002 to 2011.[8] To the best of our knowledge, no one has yet measured productivity growth in any of these industries using the deflators utilized in Section II.

Musgrave (1969) created a deflator for new single family residential construction and de Leeuw (1993) developed a deflator for new multiple family residential construction. The Census Bureau and the Bureau of Economic Analysis have extended these deflators to recent years. This section uses these deflators to create an output series for two different portions of residential construction. NAICS industry 236115, new single family housing, and NAICS 236116, new multiple family housing, clearly belong in the one family and multiple family categories. NAICS 236117, new housing, for-sale builders, very largely consists of single family homes constructed by builders who own their own land. We therefore include most of NAICS 236117 with the single family category; Census data on the actual products supplied by establishments classified in NAICS 236117 are used to assign for-sale construction to its different components.[9]

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[8] Residential construction (single family, multiple family, and for-sale builders) accounted for 18.5 percent of the total value of business done reported in the 2007 Census of Construction. For-sale builders are included in these calculations because, as described in the next paragraph, their production is included within single family and multiple family construction. When the construction of highways, streets, and bridges is also included, the proportion of construction covered increases to 24.1 percent.

The 2007 proportions mentioned in the preceding paragraph do not occur simply because the home building sector was unusually large in 2007. In the 2002 Census the same three industries account for 25.2 percent of the value of construction work. The 2002 data reinforce the point that the three industries considered in Section II provide reliable information on productivity growth for approximately one quarter of the value of construction work.

As Table 2 below indicates, in 2007 these same three industries account for only 12.2 percent of labor input in construction. Residential construction accounts for a larger proportion of output than of labor because large numbers of construction contractors contribute to the output observed in residential construction; their contribution is typically treated as materials input.

[9] We briefly considered developing a specific deflator for for-sale builders by combining the deflators for single family and multiple family construction in the proper proportions. The potential difficulty is that, over time, the hedonic characteristics of new houses are apt to change in different ways in the for-sale and other builder components of single family construction. We can unambiguously associate the well-known Musgrave deflator with all single family residential construction. However, if the characteristics of new structures diverge in the single family and for-sale components of single family housing, we cannot use the Musgrave indicator to deflate both components of this market separately.

To prepare separate deflators for single family housing and for for-sale builders, it would be necessary to know the characteristics of houses included in each group. The Survey of Construction contains annual Microdata Files which include the characteristics of houses. The Survey divides housing production into four categories. The

The other industry included is highway construction. The Federal Highway Administration (FHWA) has collected information on the cost of highway construction for many years. For most of this period the FHWA published a Bid Price Index drawn from bid prices for major contract awards for federally financed highway projects. About 2000, the FHWA developed some doubts concerning the accuracy and cost effectiveness of their Bid Price Index. In addition, a General Accountability Office (2003) report raised further questions concerning the usefulness of the Bid Price Index.

As a result of these discussions, in 2007 the FHWA introduced the National Highway Construction Cost Index (NHCCI) to replace the Bid Price Index. The new index includes a broader more representative selection of highway projects. Though released in 2007, the NHCCI provides data as far back as 2003. From its name, the National Highway Construction Cost Index certainly sounds like a cost index. However, the information is based on bids submitted on highway construction contracts. In addition, the NHCCI web site indicates:

"This web page provides a price index that can be used both to track price changes associated with highway construction costs, and to convert current dollar expenditures on highway construction to real or constant dollar expenditures."

Because the Federal Highway Administration (FHWA) index is based on actual bids submitted for highway construction contracts, it is justifiable to treat this index as an output deflator. Since the data base includes both winning and failing bids, the data provide information on both the mean and standard deviation of prices. Because the NHCCI provides data from 2003, we begin analysis of productivity growth in highways in 2002.[10]

The NAICS industry which corresponds to highway expenditures is NAICS 23731, Highway, Street, and Bridge Construction. It is important that the FHWA uses the NHCCI to deflate not only federally funded highway expenditures but also state and local highway expenditures. Specifically, the FHWA publication 2006 Status of the Nation's Highways, Bridges, and Transit: Conditions and Performance, page 6-15, shows that the FHWA uses the NHCCI deflator to deflate all forms of capital outlays on highways, including state and local highways as well as federal highways. Federal and state and local construction expenditures account for the great majority of expenditures in NAICS 23731. There is therefore ample precedent to use the NHCCI deflator to deflate this type of output.[11]

"Houses Built for Sale" category is by far the largest of these four classifications. However, it does not seem possible to distinguish between single family builders and for-sale builders within these data.

[10] The analysis begins in 2002, rather than 2003, because 2002 is a Census year. We use the Bid Price Index to measure the price increase between 2002 and 2003.

[11] The Federal Highway Administration uses the overall CPI to deflate all maintenance and repair expenditures. Different agencies define maintenance and repair in different ways, but this category includes patching the road surface, signs, guardrails, snow and ice removal, mowing, trash pickup, and toll collection. 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 use the NHCCI deflator to deflate those elements of maintenance included in the Census of Construction, because items such as patching of road surfaces and guardrails are more closely similar to construction than other portions of maintenance are.

For each of our three industries, we use data on output, on the number of employees, and on the number of partnerships and proprietorships all from the Census of Construction. The common data source is important since this ensures that these primary data items are fully consistent. Between Census years, we interpolate using annual information on output from the Census Bureau report on Value of Construction Put in Place, annual data on employment from the Bureau of Labor Statistics Current Employment Statistics, and annual data on partnerships and proprietorships from the Census data on Non-Employer Statistics. We obtain data on employee hours in each industry from the Current Employment Statistics. Data on the average weekly hours of partners and proprietors in construction are from the Bureau of Labor Statistics Current Population Survey; we have to assume that average weekly hours of partners and proprietors are the same within each industry of the construction sector. Appendix B below describes all data sources and procedures in much greater detail.

Residential construction: Output

We consider two types of residential construction, single family and multiple family construction. Single family construction consists of NAICS 236115, single family construction, plus most of NAICS 236117, operative builders, which largely consists of single family construction. Multiple family construction consists of NAICS 236116, multiple family homes, plus a small proportion of operative builders.

The main problem in measuring construction output has long been the absence of appropriate deflators. However, the Census Bureau has published a deflator for single family residential construction since the 1970s; this is a hedonic deflator which allows for the characteristics of new houses, such as square footage, the number of bedrooms, and the number of bathrooms. The Bureau of Economic Analysis similarly prepares a hedonic deflator for multiple family residential construction.

The main data on output come from the Census of Construction. We use the Census as our main data source because it is the only source of consistent data on both output and labor input. The Census provides separate information on the value of production for employer and non-employer establishments; we combine these to prepare a single measure of overall output in each industry. For intervening years, between the Census years, information on output is obtained from the Census Value Put in Place Survey; this survey is used to interpolate between the values of output observed in Census years.

The Bureau of Labor Statistics prepared a cost based PPI for NAICS 23731, Highway, Street, and Bridge Construction between 1986 and 2010. Appendix A compares the NHCCI price deflator with the BLS cost deflator for the 2003 to 2010 period during which these series overlap. The comparison shows how drastically price based and cost deflators can differ, especially during years, like 2007 to 2009, when demand is decreasing rapidly. Such results illustrate the importance of obtaining price deflators for more portions of the construction industry.

In order to prepare a comprehensive measure of industry output, secondary business activities must be included in addition to the value of construction work.[12] Table ECO723I2 of the 2007 Census of Construction, Preliminary Value of Construction Work for Establishments by Type of Construction: 2007, provides detailed information on the production actually produced by all establishments classified in a given NAICS industry. We divide the production observed into four categories. The first is production primary to the industry. The second is secondary production within construction for which we have acceptable deflators, that is secondary production in single family housing, multiple family housing, and highways, streets, and bridges. The third category is secondary production in construction for which we do not currently have acceptable deflators, namely production outside our three industries. The fourth category is miscellaneous business activity, essentially outside construction.

The third category, production in other elements of construction, presents a problem since no good deflators are available for these industries. In 2007, 3.8 percent of the production of establishments in the single family construction industry, 18.1 percent of multiple family housing, and 11.9 percent of the production in highways, streets, and bridges consisted of secondary construction products for which no good deflator is available. Such percentages of un-priced secondary products are not unusual in Bureau of Labor Statistics measures of industry productivity, especially outside manufacturing. As is standard practice, in these instances the price of the primary product is used to approximate those secondary products for which no reliable price information is available. The output of primary products and the output of each of these types of secondary production are then combined into a single index of overall output using Tornqvist aggregation. The result is an index of overall output for the single family homes industry and a similar index of output for the multiple family homes industry, each from 1987 to 2011.

Figure 1 shows output trends, for both single family and multiple family residential construction, from 1987 to 2011. The solid line, which represents single family construction, reaches a peak before the dashed line, which shows the output of multiple family homes, does.[13] The difference between the total index of single family output and the dotted line, which shows the quality of single family houses as obtained from the hedonic measures, reflects the increased volume of single family houses.

The measures of output growth shown in Figure 1 are quite plausible. Housing output declined during the recession of the early 1990s. Output grew steadily throughout the 1990s, and expanded rapidly from 2002 to 2006 or 2007. Production declined steeply after the boom, and stabilization began in 2009 or 2010. Most of boom output consisted of an increased number of units, but single family house quality also increased modestly during the boom years.

[12] The main products produced in an industry are called primary products. Secondary products are other products, not normally included in the industry, which establishments assigned to an industry also produce. Appendix B describes the treatment of secondary products in detail.

[13] Multiple family housing may lag behind single family housing because projects take longer to complete.

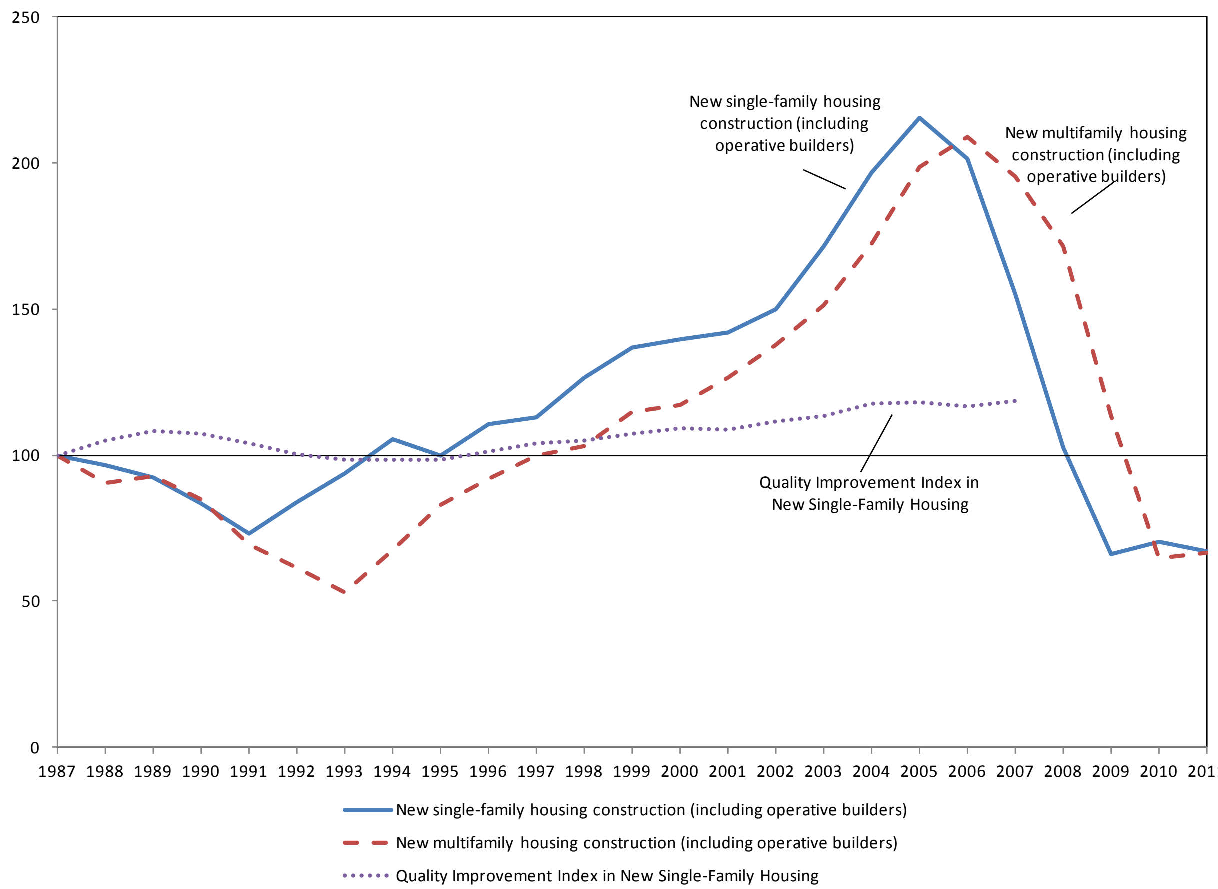

Figure 1 Output growth in Single and Multiple Family Residential Construction, 1987-2011.

Residential construction: Labor Inputs.

Labor inputs are also obtained from the Census of Construction. The Census provides data on both the number of employees and the number of partnerships and proprietorships in each industry in each Census year. Data on average weekly hours of paid employees in each construction industry are obtained from the Bureau of Labor Statistics Current Employment Statistics (CES). Information on the hours of partners and proprietors in construction is obtained from the Bureau of Labor Statistics Current Population Survey (CPS); since the CPS provides information only on construction in general, partners and proprietors are assumed to have the same average weekly hours in all industries of the construction sector. For the years between Census years, employment in each industry is interpolated on the basis of

annual data from the Current Employment Statistics.[14] From 1997 to 2011 the number of partners and proprietors is obtained from the Census Bureau Non-Employer Statistics program. Since the Non-Employer Statistics series begins in 1997, between 1987 and 1997 partners and proprietors are interpolated on the basis of paid employees in each industry. Finally, total labor inputs are calculated as the sum of employee hours and partner and proprietor hours.

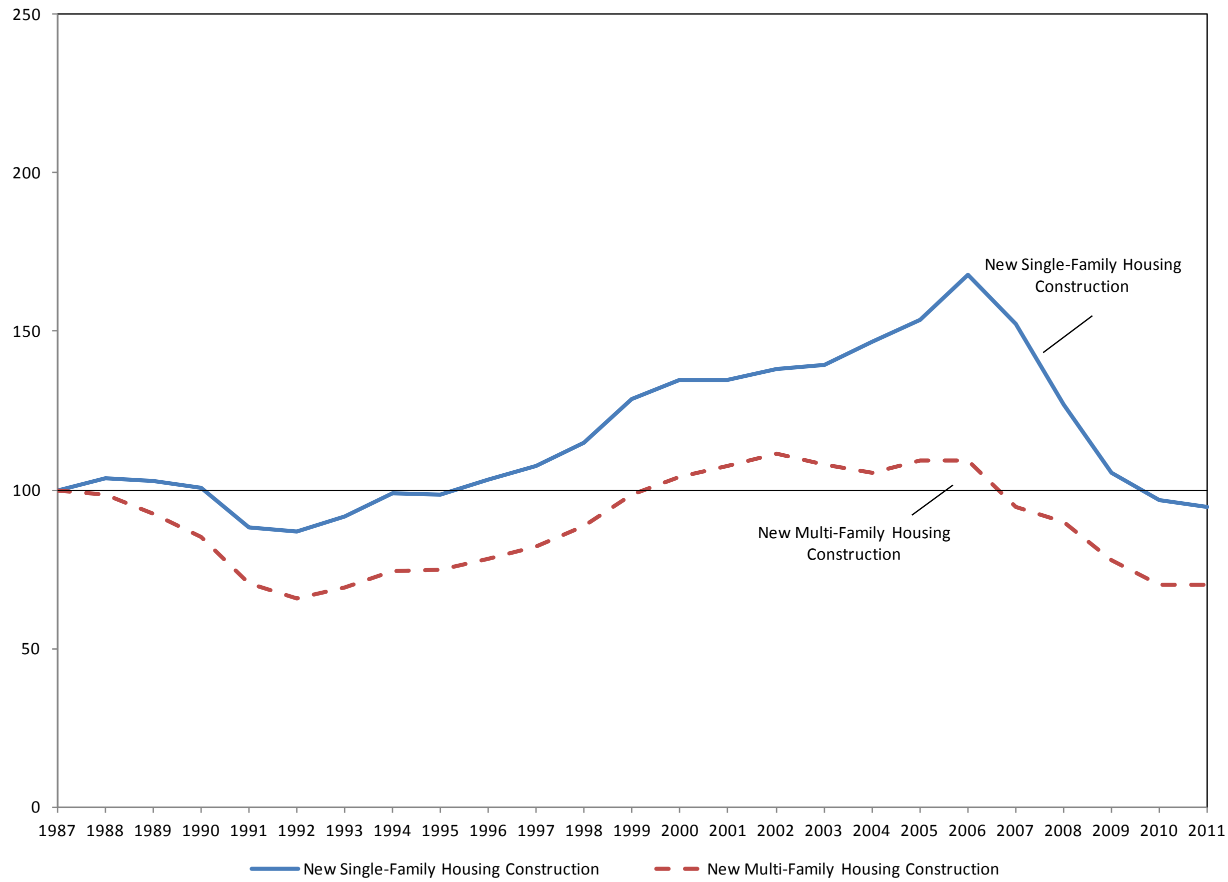

Figure 2 Total Labor Input for Single and Multiple Family Construction, 1987-2011.

Figure 2 shows total labor inputs for single and multiple family residential construction. Labor input follows similar cyclical fluctuations in the single and multiple family categories, but the labor input index is consistently greater for single family homes. During the boom period of 2000 , labor inputs tend to increase more slowly than the output index shown in Figure 1, suggesting that labor productivity increased substantially.

<u>Residential construction</u>: <u>Labor Productivity</u>.

[14] Since output and labor are both benchmarked to the Census of Construction, data for the intervening years must be revised whenever a new Census of Construction becomes available. For example, all the estimates of productivity growth in 2008-2011 will have to be revised once the 2012 Census of Construction is released.

Figure 3 reports labor productivity for new single-family and multi-family housing construction. Over the entire 1987 to 2011 period, labor productivity in single family housing declined at an annual rate of -1.4 percent. Over the same period, the productivity of multiple family housing declined at a rate of -0.2 percent. However, these declines reflected the sharp productivity declines which occurred after the boom. From 1987 to 2005, productivity increased 1.9 percent annually for single family homes and 3.3 percent annually for multiple family homes. Labor productivity was relatively stagnant for both new single-family and multi-family housing construction until 1995. After 1995, however, the long term productivity rate, the trend since 1987, was consistently positive. In 2002 productivity growth rates increased sharply, peaked in 2005 to 2007, and then declined steeply.

Two strands of evidence indicate that the long-term rate of productivity growth has been positive in residential construction. First, before the boom, from 1987 to 1995 or from 1987 to 2000, long-term productivity growth was positive; the recession of 1991-1992 hindered housing, but once the economy had recovered, the long-term productivity trend is clearly positive. Second, as Figures 1 and 3 show, the index of output and the level of productivity follow closely similar time paths. As housing starts return to more normal levels, observed long- productivity growth is likely to revert to positive growth.[15]

Following the output numbers, productivity in single family housing reached its peak a few years before multiple family housing did. However, the productivity index eventually fell sharply in both segments of the industry. Output trends are roughly comparable in single and multiple family homes (Figure 1), but labor inputs are consistently greater in single family building (Figure 2). Consequently, productivity growth is greater in multiple family homes (Figure 3).

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[15] Relevant regression results support these comments. For example, in annual data for 1987 to 2011 for single family residential construction

$$\log(O/L) = -10.25 + .521\log(\text{Housing Starts}) + .00625\text{time}$$
$$\text{t ratios} \quad (-4.16) \quad (22.05) \quad (5.15) \qquad \bar{r}^2 = .953$$

For multiple family residential construction:

$$\log(O/L) = -53.96 + .366\log(\text{Housing Starts}) + .02864\text{time}$$
$$\text{t ratios} \quad (-5.27) \quad (3.80) \quad (5.66) \qquad \bar{r}^2 = .590$$

The housing start variables are specific to the type of construction being considered. The coefficients for time both indicate significant and rather substantial labor productivity growth, at a rate of 0.6 percent a year in single family housing and 2.9 percent in multiple family residential construction.

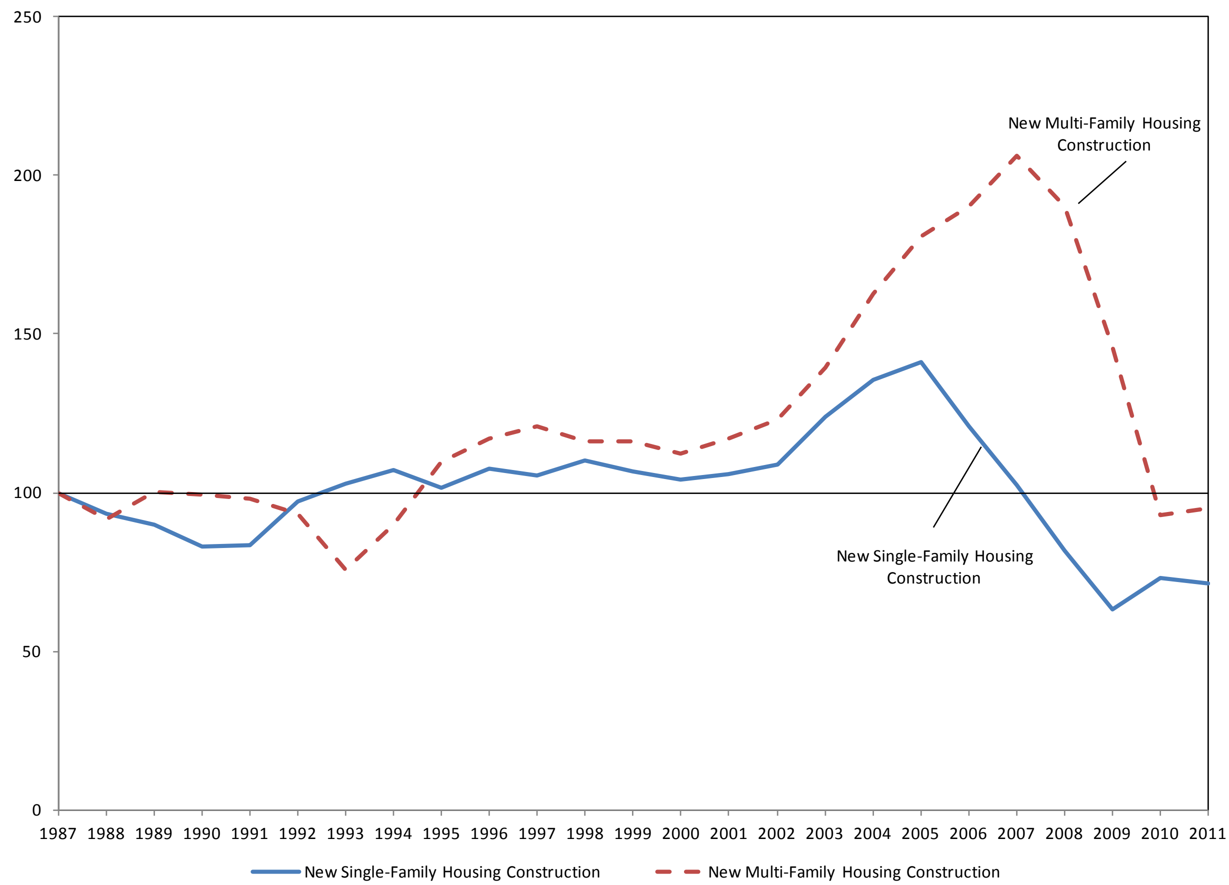

Figure 3 Labor Productivity for New Single and Multi-Family Residential Construction, 1987-2011.

Figure 4 below shows output, labor inputs, and labor productivity within NAICS 23731, the construction of highways, streets, and bridges. Overall, labor productivity in highways, streets, and bridges increased 5.6 percent a year between 2002 and 2011. For shorter time periods, observed labor productivity trends in this industry contrasted sharply with those observed in residential construction. During the housing boom of the 2000s, when residential construction experienced a substantial burst in labor productivity, output and labor productivity both declined in highway construction. After labor productivity in residential construction began to decline precipitously in 2005, labor productivity in highway construction began to rise and this industry experienced a substantial surge in labor productivity between 2008 and 2009. After 2009, labor productivity in highway construction was once again stagnant.

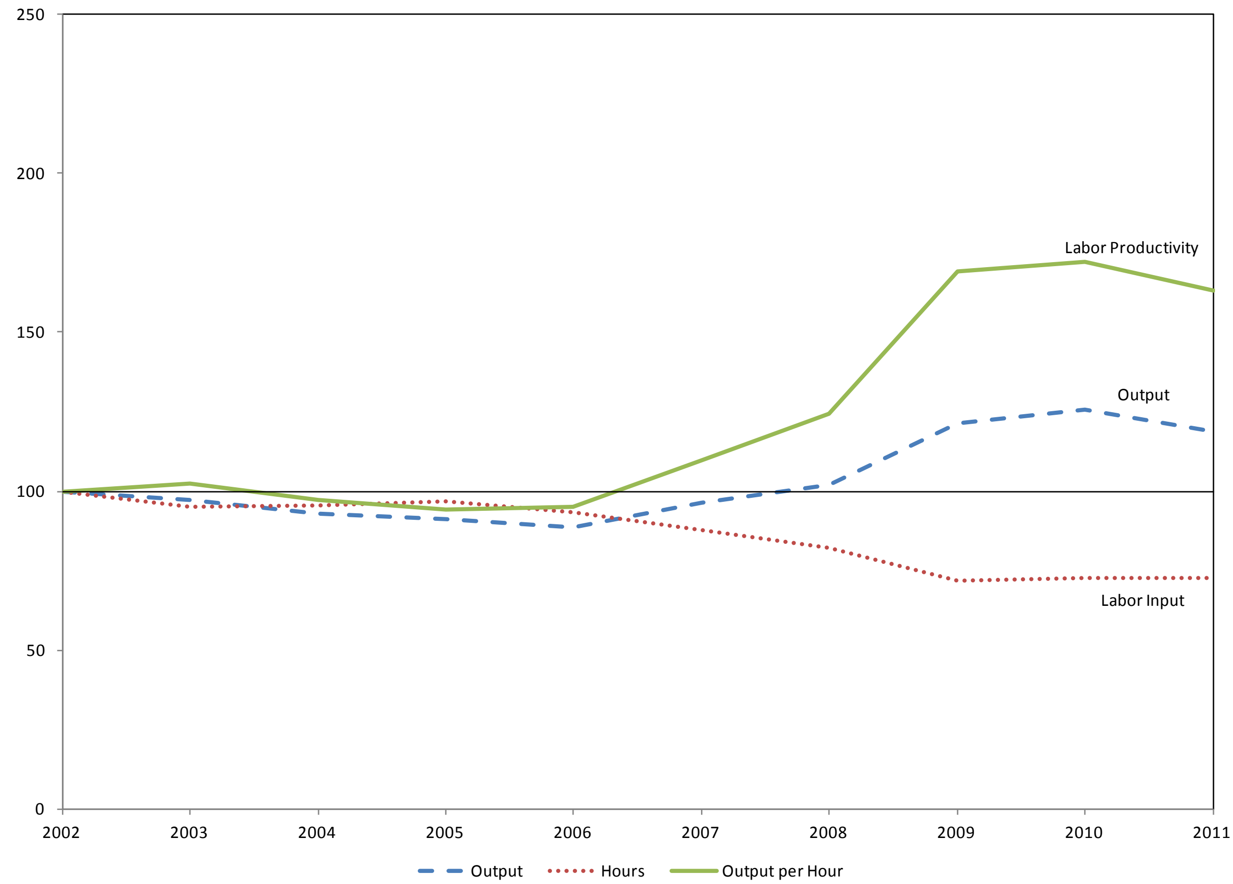

Figure 4 Output, Labor Input, and Labor Productivity in the Construction of Highways, Streets, and Bridges, 2002-2011. NAICS 23731.

Several cross currents are likely to have affected output and labor productivity growth in highways, streets, and bridges. Output and productivity growth both began to increase as early as 2006. Later, as part of the response to the steep decline in the economy, the federal government undertook a stimulus program, part of which was associated with expenditures on roads and highways. At the same time, many state and local governments fell into budget difficulties, and presumably reduced their expenditures in this area. The net effect was an increase in output which is likely to have contributed to the productivity growth observed for highways after 2008.

At the same time there may been a compositional shift as federally financed expenditures, perhaps more capital intensive, replaced state and local expenditures. For example, the data indicate that

between 2008 and 2009 the proportion of self-employed workers, presumably those most closely associated with smaller scale construction projects, declined rapidly.

At any rate, good information is now available on productivity growth in three important components of the construction industry. The evidence from these industries does not indicate that there has been a substantial decline in productivity. It is true that productivity in residential construction declined, at -1.4 and -0.2 percent, between 1987 and 2011. However, these declines essentially reflect the collapse of the housing construction industry which occurred after 2005. From 1987 to 2005, productivity in residential construction increased steadily, at 1.9 and 3.3 percent. More meaningfully, the 1987 to 2000 or 1987 to 2002 periods, before expansion crested, shows no evidence of a productivity decline in these important segments of the construction industry. In addition, the highways, roads, and bridges component of the industry shows a productivity increase, though the trend observed in this portion of the industry at least partially is likely to reflect countercyclical expenditures.[16]

So far, we have looked only at labor productivity. By the end of 2013, our measures will also incorporate the influences of materials deepening and, to the extent possible, at least as an approximation, the effect of capital deepening. Consistent with equations (1) or (2), our work will attempt to provide at least rough indicators of multifactor productivity growth within each of the three industries considered here.

Beginning in 2006 and 2007, the Producer Price Index (PPI) group of the Bureau of Labor Statistics has published PPIs based on output prices for eight additional industries in construction.[17] Once the 2012 Census of Construction is published, so that we can benchmark both output and employment data to the 2012 Census of Construction, we plan to construct further measures of labor productivity growth for most of these additional industries. The work reported here, in Section II, is in a sense a prototype. Any comments or suggestions concerning the appropriate development or analysis of the three industry measures outlined above, in residential construction and in highways, will eventually also be used in the measures planned for further industries.[18]

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[16] A reviewer has raised the valid point that the Census of Construction typically reports the year in which construction is completed rather than the year that construction activity occurs. The Census made this choice because they found that firms are usually not able to report the year in which construction activity actually occurs. Such lumpiness suggests that estimates of year to year productivity growth may be subject to considerable error. On the hand, long-term measures will be much less affected by this problem; long-term measures should perhaps be prepared as three-year averages at the beginning and end of the long-term periods to avoid this potential difficulty.

[17] The new improved PPIs are not based on actual construction prices. Instead, following the lead of the Canadian and Australian statistical agencies, the Bureau of Labor Statistics establishes a typical building for each of four areas of the country. They then price the cost elements for these typical buildings. In addition, the Bureau surveys builders monthly to determine the gross margin charged above observed costs.

[18] The improved PPI measures now cover industrial buildings, commercial warehouses, school buildings, office buildings, and the nonresidential portion of contractors in the concrete, roofing, electrical, and plumbing, heating, and air conditioning fields.

As we move towards measuring multifactor productivity growth in the three industries emphasized in this paper and in the additional industries covered by the new improved PPIs, there are several issues on which we would appreciate comments. To what extent is it realistic to attempt to prepare measures of multifactor productivity growth for our three industries and, eventually, for other industries as well. Several problems arise in calculating MFP in these construction industries. First, it is difficult to determine many of the relevant materials prices. We can easily measure materials prices for standard input items such as concrete, lumber, and plumbing supplies. It is much more difficult to measure the input price for materials purchased from contractors, since we do not have reliable price deflators for most contractors; nevertheless, the PPI now does provide some reliable information on contractor prices, such as the price index for electrical contractors, except residential. The new PPI data provide us with ballpark information on at least some contractor output prices. However, a second, and more intractable, problem is that builders formerly purchased labor and other inputs themselves, but now frequently purchase an equivalent bundle of inputs from an outside supplier. This sort of outsourcing shows up in the data as the purchase of services. A builder may purchase $50,000 worth of services from one supplier and $100,000 from another supplier. Unfortunately, we do not know enough about exactly what is included in these many purchased services. In some cases, purchased services may replace a builder's own labor and materials. In other instances the contractor may purchase his labor from an outside supplier, who may be able to pay lower wages. In many instances, suppliers may provide builders with the labor of illegal immigrants or of domestic workers similarly working off the books. In the absence of reliable information on the content of purchased services, it is very difficult to price purchased services or to determine the extent to which they replace labor inputs. Our measures of labor input over time may be questionable because, over time, service providers provide increasing amounts of legal or illegal labor input. We are aware of these complex issues, and would appreciate any suggestions.[19]

A further limitation arises from the lack of data on capital investment. The Census of Construction reports information on investment in structures and related facilities, and in machinery and equipment for each detailed industry. In recent years, the machinery and equipment data include detailed information for the autos and trucks subcategory. However, there is little information on capital investment by industry in the intervening years between Censuses.[20] To what extent is it feasible to develop rough estimates of the plant and equipment capital stock in each industry and determine service prices from BLS service prices for the aggregate construction sector? Capital shares are small in most construction industries. To what extent can we obtain a very rough estimate of the effect of capital deepening in each industry from such methods?

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19 Section IVB below examines whether standard establishment data, the traditional basis for productivity measurement, systematically understate the employment of illegal aliens.

20 The American Capital Expenditures Survey (ACES) provides information on annual expenditures for investment between Census years, but in construction ACES covers only three broad industries, essentially housing construction, heavy construction, and contractors, and the data begin only in 1994.

Another important area of concern arises because the industry coverage available from the Census of Construction, which is collected on a NAICS basis, often does not match the industries for which new improved PPIs are available. The data below illustrate how industry coverage provided by the Census of Construction differs from the industry boundaries covered in the new improved PPIs.

	NAICS Industry	PPI Coverage
236210	Industrial Building Construction	Industrial Building Construction
236220	Commercial and Institutional	Office Buildings
236220 cont	Building Construction	Schools
236220 cont		(Commercial) Warehouses
23811	Concrete Contractors	Concrete Contractors. Except Residential
23816	Roofing Contractors	Roofing Contractors, except Residential
23821	Electrical Contractors	Electrical Contractors, except Residential
23822	Plumbing, Heating, and AC Contractors	Plumbing, Heating, and AC Contr, exc Residential

In NAICS 236220, the PPI does not cover Hospitals, Churches, Stores-Restaurants, and many other types of commercial and institutional construction.

Under these circumstances, we believe we have to go inside the establishment micro data of the Census of Construction to find exactly those establishments which produce office buildings, schools, or Plumbing, Heating, and Air Conditioning Contractors, except Residential. The Census of Construction reports on all recognized NAICS industries. We feel we have to go inside the micro data, to establish industries more detailed than the current NAICS, and collect information on output, employment, and the presence of partners and proprietors in quasi-NAICs industries which produce exactly what the PPI is pricing.

We would appreciate any thoughts as to whether it is a good idea to go inside the Census of Construction micro data, to define and measure productivity in more narrowly defined industries which match the new PPIs. Is this a good idea? We think that such work is warranted and illustrates the detailed way in which future Bureau of Labor Statistics production work could benefit greatly from access to Census micro data.

III. Shifts Among Industries.

Allen (1985) concluded that, between 1968 and 1978, labor productivity growth was negative in the overall construction industry partially because low productivity portions of the industry were growing more rapidly. His evidence (page 665) showed that industry shifts reduced productivity by 4.5 percent over the decade, which translates to approximately .44 percent a year. This section examines the role of interindustry shifts by observing levels of labor productivity in 1987 and testing the hypothesis that labor inputs systematically grow more slowly in high productivity industries. The measures of growth of

labor input always include partners and proprietors, who play a substantial role in many portions of construction.[21]

To begin discussion of labor shifts, the 2007 Census of Construction reports data for 31 different five-digit or six-digit industries. We include NAICS industry 237210, land subdivision, even though this sector was classified as SIC 6552 in 1987. Table 2 lists the 31 industries which form the basis for analysis throughout this section.

To understand the impact which labor shifts since 1987 have had on aggregate productivity[22], consider the following identity:

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

in which overall labor productivity, $\overline{O/L}$, is determined as the summation 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, we first calculate relationship (3) for 1987 using 1987 labor input weights for each industry. We then examine what 1987 productivity would have been if 2007 labor input weights were used instead. The difference shows how much lower output, and productivity, would have been in 1987 solely because of the labor input shifts observed by 2007. Such estimates provide a rough indication of productivity losses due to the shift in the distribution of labor hours observed between 1987 and 2007. [23]

Table 2 also reports the share of hours in each industry in 1987 and 2007 and measures of labor productivity, O/L, for each industry in 1987. The reader may note that Table 2 indicates that productivity is considerably higher in residential construction than in many other portions of construction, especially the contractors covered in NAICS 238. How does this square with Allen's (1985) contention that residential construction is much more labor intensive? Allen only considers the output of single family homes, office and industrial buildings, and educational and hospital buildings. Many contractors presumably work on home building, which increases labor intensity and reduces productivity in residential construction. We adopt an approach different from Allen's for two reasons. First, since we are interested in all of construction, we prefer to examine shifts among all 31 industries instead of selecting just a few of them. Second, we prefer to examine shifts in labor rather than shifts in output. The problem with framing the analysis in terms of output growth is that, since output deflators

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[21] Partners and proprietors account for a substantial portion of labor inputs in construction. According to data prepared by the Division of Major Sector Productivity of the Bureau of Labor Statistics, partner and proprietor hours accounted for 19.3 percent of the total hours in construction in both 2002 and 2007.

[22] We examine labor shifts over time because, in the absence of accurate output deflators, it is not possible to measure output shifts accurately.

[23] One could perform a similar exercise for 2010, examining the impact of the distribution of labor input in 1987 and in 2010. However, $(O/L)_i$ and shl_i in 2010 are jointly determined by many factors such as technology or demand conditions. For the purposes of a 1987-2010 analysis, it is preferable to treat $(O/L)_i$, as observed in 1987, as a predetermined variable.

are not available, the output series mix true output and price changes, with these combined in unknown proportions.

Table 3 presents empirical results from equation (3). Over the full 1987 to 2007 period industry shifts reduced output appreciably. Labor shifts reduced output by .252 percent a year, which rounds off to a full 0.3 percent a year. This is a considerable impact, although not as great as Allen's estimate of .44 percent a year from 1968 to 1978.

Table 1 in Section I showed that labor productivity declines in construction were relatively modest from 1987 to 1997, perhaps in the range of -0.2 percent a year. However, the productivity decline was far more rapid in 1997-2007, in the range of -1.2 percent a year. In contrast, losses due to reallocation towards lower productivity industries were stronger in 1987-1997; in these years reallocation reduced labor productivity growth by .34 percent a year. However, during 1997-2007 the decline due to labor transfers was only .16 percent a year. Although industry shifts have a considerable impact, they do not do as well in explaining the timing of observed productivity declines.

Allen is correct that construction output shifted towards housing in 1968-1978. The present evidence indicates that labor shifts reduced construction productivity approximately 0.25 percent a year between 1987 and 2007. This is a considerable effect. However, industry shifts in themselves are not sufficiently great to provide a general answer as to why construction productivity has kept on declining, especially during the most recent 1997 to 2007 period.

Finally, we consider the difficult question of why construction labor may be shifting towards apparently lower productivity uses. In Allen's analysis, the critical point was that from 1968 to 1978 labor was shifting towards single family residential construction, which is more labor intensive than many other elements of construction. In Table 2 the housing industries still lose some labor share between 1987 and 2007, but the dominant shift instead represents a transfer of resources from heavy construction to contractors. Why would resources shift to lower productivity industries when resources much more typically flow from low to high productivity uses? Perhaps small contractors, who are far less capital intensive, are more nimble and can be managed more effectively than the larger labor forces characteristic of heavy construction. Contractors may actually have greater overall productivity. The only way to test this possibility and to understand the observed pattern of growth of different industries and the increased reliance on subcontractors, is to calculate multifactor productivity growth for a large number of industries in construction, including many contractors. Fortunately, the work plan outlined in detail in Section II aims at producing precisely such information.

IV. Regulation.

It is quite plausible that, when environmental regulations are binding, producers have to spend some resources meeting these obligations so that a smaller proportion of inputs is available to produce conventionally measured output (Greenstone, List, and Syverson (2012)). Similarly, it is reasonable that when environmental restrictions are greater, a greater proportion of inputs must be used to meet these requirements.

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 which 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. Since 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 (2012) show that their measure of land use limits is correlated with prior measures of actual land use restriction in different geographic areas.[24]

The Ganong-Shoag measure appears to be an excellent fit for construction. Land use law in all its ramifications limits housing development, office and store development, and many other forms of construction. This measure of regulation may also reflect broader environmental concerns. The existence of regulations will therefore limit observed productivity. Specifically:

$$\log(V/L)_{i,j} \quad = \quad a \quad + \quad b\log(Reg)_{i,j} \qquad (4)$$

where $(V/L)_{ij}$ is value added per unit of labor in state i in year j, and $(Reg)_{ij}$ is the cumulative amount of regulations binding in each observation, as measured by the Ganong-Shoag index Note that equation (4) is expressed in terms of real value added, $V_{i,j}$, rather than gross output, $O_{i,j}$, because the Bureau of Economic Analysis publishes data only on gross product originating, or value added, for the construction industry in each state.[25] The logarithmic form is selected because an increased amount of regulation, say a linear increase from .8 to .9, does not necessarily have the same impact as an increase from .1 to .2. The empirical data in fact do support the linear in logarithms form. The central hypothesis is that the presence of regulations has a negative effect on observed productivity, so that $\hat{\beta}$ in equation (4) is negative.

In considering estimation of equation (4) across different states from 1977 to 2010, states with high levels of regulation are likely to differ from other states in many other characteristics as well.[26] It is therefore necessary to include a complete set of state fixed effects dummies in the analysis. This framework ensures that any effects attributed to regulation reflect genuine effects of regulation within

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[24] r^2 between the Ganong-Shoag index and an explicit measure of regulation prepared in a survey conducted by the American Institute of Planners in 1976 is .23. r^2 between the Ganong-Shoag land use index and the Wharton Residential Land Use Regulation Index, prepared in 2005, is .36.

[25] Consequently, all estimates of the effect of regulation throughout this section refer only to gross product originating, which is a value added concept. No direct information is available on gross output productivity.

[26] For example, states such as California or Connecticut with high levels of regulation differ in many important respects from states such as Alabama or Texas which have low levels of regulation. To avoid conflating regulation with other characteristics of states we often include state dummies in the analyses.

As Grossman and Krueger (1995, page 372) remark "As nations or regions experience greater prosperity their citizens demand that more attention be paid to the noneconomic aspects of their living conditions." The extent of regulation may therefore be associated with observed incomes. Regulations and related factors may also limit construction productivity in other countries. Lewis (2004) considers construction productivity in Japan (pages 40 to 42) and in Europe (pages 67 to 69).

the individual states rather than any external factors correlated with state characteristics. In addition, estimation should allow for time effects, either through a time trend or, more flexibly, through a complete set of time dummies.

Table 4 reports several estimates of the effect of regulation on labor productivity from pooled state and year data. Columns (1) and (2) report a linear form, in which $\log{(Reg)_{i,t}}$ determines $\log{(V/L)_{i,t}}$. In column (2) the time dummies perform far more strongly than the continuous time variable in column (1). All the rest of the analysis in Section IV therefore adopts the more flexible time dummy form. In this levels form, an F test clearly supports the inclusion of state dummies.[27] Column (3) examines a rate of change version, in which the rate of change of regulation, $\log{(Reg)_{i,t}} - \log{(Reg)_{i,t-1}}$, helps explain the annual change in productivity, $\log{(V/L)_{i,t}} - \log{(V/L)_{i,t-1}}$. The first difference form removes time trends which can introduce spurious correlation in level forms. On the other hand, year-to-year variations in productivity growth introduce substantial measurement error. In addition, it is by no means clear that current changes in regulation should immediately influence productivity growth, with no allowance for lags. Nevertheless, estimates based on the rate of change form are broadly consistent with the other estimates, although the estimates in column (3) are less precise.

Column (4) shows the impact of regulation in the rate of change version without state dummies.[28] The estimate, at $-.036$, falls broadly within the range of the other estimates. The evidence suggests though, though state dummies were crucial in the levels regressions, they are not necessary in the rate of change version; first differencing has swept out heterogeneities between states. Finally, column (5) reports a version in which the level of regulation is included as well as the growth of regulation. Though column (5) manages to distinguish between two separate effects, explanatory power (r^2) does not increase appreciably.

Overall, the various estimates fall into a relatively narrow range of -.036 to -.047. In addition, each estimate of the effect of land use regulation on productivity is significantly less than zero at a 95 percent level. We select the value $\hat{\beta} = -.0400$, close to the middle of the range of the various available estimates, as our primary measure of the effect of regulation on productivity growth.[29]

Once our main estimate of $\hat{\beta}$, $-.0400$ from column (3) of Table 4, has been determined, how do we use this parameter to measure the impact of regulation upon productivity growth in construction? Equation (4) can be rewritten in first difference form as:

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[27] The F ratio with 47 and 1551 degrees of freedom is 67.3, far greater than the 95 percent significance level of approximately 1.36.

[28] In fact, an F test cannot reject the null hypothesis that all state dummies are equal to zero. The F value is .78, which is lower than the 95 percent F value of 1.36 with 50 and 1500 degrees of freedom. F tests similarly suggest that state dummies are not required in the analysis of Table 5. Apparently, the first differencing suffices to sweep out individual state effects. Consequently, all the rest of the estimates in Section IV do not include state dummies.

[29] An elasticity of -.04 implies that a 100 percent increase in regulation reduces productivity by 4 percent. In 2010 Reg was $.0007698$ in Alabama and $.0338765$ in Maine. The index of regulation therefore doubles at least five times between the lowest and highest regulation states, which implies a productivity decline of 20 percent.

$$\log(V/L)_{i,t} - \log(\mathrm{V/L})_{\mathrm{i,t-1}} = \hat{\beta}\,(\log(\mathrm{Reg})_{\mathrm{i,t}} - \log(\mathrm{Reg})_{\mathrm{i,t-1}}) \quad (4b)$$

in which the rate of growth of regulation, since $\hat{\beta}$ is negative, reduces the rate of growth of labor productivity.

Consider that, in the absence of any year-to-year increase in regulation, observed log$(V/L)_{i,t}$ would be higher in equation (4b). Specifically,

$$\log(V^{*}/L)_{i,t} = \log(V/L)_{i,t} + .04(\log(Reg)_{i,t} - \log(Reg)_{i,t-1}) \quad (4c)$$

where the new V, $V^{*}_{i,t}$, is the amount of output that would have occurred in the absence of any regulatory increase.

The new $(V^{*}/L)_{i,t}$ can be calculated from (4c) as[30]

$$(V^{*}/L)_{i,t} = \exp\,[\log(V/L)_{i,t} + .04(\log(Reg)_{i,t} - \log\big(Reg)_{i,t-1}\big)] \quad (4d)$$

Since $\exp(x+y) = \exp(x) * (\exp(y)$,

expression (4d) is equal to:

$$(V^{*}/L)_{i,t} = (V/L)_{i,t} * \exp\,(.04(\log(Reg)_{i,t} - \log(Reg)_{i,t-1})$$

in which the second term expresses the multiplicative amount by which $(V/L)_{i,t}$ is increased due to the absence of any regulatory increase. Since $L_{i,t}$ is assumed to be unchanged, $\exp\,(.04(\log(Reg)_{i,t} - \log\big(Reg)_{i,t-1}\big))$ at the same time also expresses the multiplicative increase in $V_{i,t}$.

By cumulating the new V^{*}values across the 48 states in each year, we can determine $\sum_{1}^{48} V^{*}$. Similarly, by cumulating the existing V_i values for each state we can determine $\sum_{1}^{48} V$. Then:

$$(\textstyle\sum_{1}^{48} V^{*} \,/ \sum_{1}^{48} V) - 1.0 \quad (5)$$

determines the percentage loss in construction output which occurs each year, at the aggregate level, because of increases in regulation. These calculations are carried out for each year, so equation (5) provides information on both the annual loss to construction productivity, and the time path of losses over time.

However, it is not necessary to assume, as in equation (4b), that regulation affects productivity only through a linear in logarithms (percentage rate change) relationship. For example, in Wyoming regulation grew at a very rapid rate, but started out at an extremely low level. We therefore next examine a more general model in which the same percentage increase in regulation affects productivity growth more severely in high regulation states.

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30 We take the exponent of both sides of equation (4c). $\exp(\log(V^{*}/L)_{i,t} = (V^{*}/L)_{i,t}$.

As in standard in growth accounting, then, the same percentage increase in regulation may hold back productivity more strongly when the share of regulation is high. Specifically

$$\log\big(V/L\big)_{i,t} - \log\,(V/L)_{i,t-1}\big) \quad = \quad \alpha_{REG}(log(Reg)_{i,t} - log(Reg)_{i,t-1}) \qquad (4e)$$

(4e) allows increases in regulation to have a greater impact when the level of regulation is higher.[31]

We do not know α_{REG}, regulatory costs as a share of output. However, we do have information on land use regulation as a proportion of overall appellate cases. As a first approximation, we assume that the regulatory share of total costs is a multiple of the share of regulatory cases in total cases. For example:

$$\alpha_{REG} \quad = \quad \beta m \alpha_{CASES}$$

where a_{CASES} is the proportion of cases which involves land use, and m is a multiple which converts the share of legal cases into regulatory costs as a share of production costs. There may not be a one to one correspondence between a_{Reg}, the share of cases, and the share of costs accounted for by regulation; it is quite plausible that x proportion of cases may consistently be associated with 2x proportion of costs.

Then:

$$\log(V/L)_{i,t} - \log\,(V/L)_{i,t-1} \quad = \quad \hat{\beta} m\, a_{CASES}(log(Reg)_{i,t} - log(Reg)_{i,t-1}) \qquad (4f)$$

In the context of expression (4f) we not need to know the value of β but only the joint product βm. Equation (4d) then becomes:

$$(V^{*}/L)_{i,t} \quad = \quad \exp\,[\log\,(V/L)_{i,t} \; + \; \beta m \alpha_{CASES}(\log\,(Reg)_{i,t} \; - \log\big(Reg)_{i,t-1}\big)]$$

and all we need to determine the output lost due to increases in regulation is an estimate of the joint product βm which can be obtained from a regression based on equation (4f).[32]

In principle, it is also possible to assume that the relationship between the share of legal cases and the share of costs is linear, so that $\alpha_{REG} \; = \; a + \mathrm{b}\, m\, \alpha_{CASES}$. However, our estimate of a is not significantly different from zero when we explore such possibilities.[33]

Empirical results from equation (5), based on the coefficients in Table 4, indicate that observed increases in regulation have consistently had a slight negative effect on productivity growth in

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[31] In the empirical analysis, the share of regulation is measured by $\alpha_{REG,i,t-1}$, the share of regulation observed in the previous year. This form is adopted to reduce collinearity between α_{REG} and $\log\,(Reg)_{i,t} - \log\,(Reg)_{i,t-1}$.

[32] In this version, the growth of regulatory limitations reduces productivity growth through increase in α_{CASES} as well as through the direct growth of $\log\,(Reg)_{i,t} - \log\,(Reg)_{i,t-1}$.

[33] If the share of regulation in total costs, α_{REG}, is equal to $a + bm(share\ of\ cases)$ then the share weighted effect of increases in regulation $\alpha_{REG}(\log\,(Reg)_{i,t} - \log\,(Reg)_{i,t-1})$ equals $a(\log\,(Reg)_{i,t} - \log\big(Reg)_{i,t-1}\big) + bm\alpha_{CASES}(\log\,(Reg)_{i,t} - \log\,(Reg)_{i,t-1})$. However, in column 3 of Table 5 the estimate for the coefficient of $(\log(Reg)_{i,t} - \log\,(Reg)_{i,t-1})$) is not significantly different from zero.

construction. However, there is no evidence that regulation has had a major impact, such as would be required to explain the major productivity declines observed in Table 1. Over the entire 1977 to 2010 period regulation reduced productivity growth by .086 percent a year, which, rounded off, implies an annual productivity loss of only 0.1 percent a year. The negative impact of regulation declined somewhat over time. From 1977 to 1987 the annual loss was .125 percent a year. From 1987 to 1997 the loss was .052 percent a year. From 1997 to 2010, the negative regulation effect was .047 percent a year.

Table 5 considers the alternative specification described in equation (4e) in which the effect of the growth of regulation also depends on the implied share of regulation. The third column reports estimates with the rate of change of regulation and the rate of change weighted by the regulation share both included as separate independent variables. The data clearly prefer the share weighted version, although columns (1) and (2) indicate that there is not much difference in the explanatory power provided by each variant. When the share weighted version is used to estimate the effect of regulation on productivity growth, the estimated long-term effect is slightly greater, at .104 percent a year instead of .086 percent, but this still rounds off to a long-term effect of 0.1 percent a year. In addition, the share weighted model suggests that regulation has approximately the same impact over time, whereas the constant return model implies that the productivity impact of regulation declines steadily over time. From this point of view, as well, the share weighted model seems more plausible.[34]

Since the average value of the share of cases involving land use is approximately .005 in the total sample, and since the preferred coefficient for $\alpha_{CASES}(\log(Reg)_{i,t} - \log(Reg_{i,t-1}))$, in column (2) of Table 5, is -11.45, the implied factor share for regulation is -11.45 x .005 in the average observation. This represents a negative effect equivalent to 5.7 percent of total costs in construction.[35] Since the share of cases increases over time, the implied cost share of regulation is greater in more recent years.

We therefore conclude that regulation has had a significant negative effect on productivity growth in construction, but that the implied impact on the productivity losses described in Section I has been slight.[36] Future work will examine the relationship between regulation and productivity growth with a broader approach. For example, we shall investigate whether regulation has different effects in predominantly rural areas or in states dominated by large metropolitan centers. In addition, we may experiment with different lag structures.[37]

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[34] F tests again reject state dummies in Table 5.

[35] Of course, since output is defined as value added throughout this subsection, the estimated share is 5.7 percent of value added costs.

[36] According to the specification adopted in equation (4b), productivity is more adversely affected in individual states where regulation increases more rapidly. For example, regulation reduced productivity by .10 percent a year in California and by .15 percent a year in Connecticut. Regulation decreases productivity by .15 percent or more a year in 7 of the 48 states.

[37] However, since the Ganong-Shoag measure is cumulative, considerable lags are already built into the index.

Some of the positive effects of regulation no doubt do not appear in the productivity numbers. Regulation is likely to improve compliance with building codes, such as the security of the electrical system or protection of houses from hurricanes or water damage. These upgrades provide consumers with protection, such as freedom from electrical fires. However, such improvements are not likely to appear in construction output. Even when hedonic methods of output are in use, such improvements are too specialized to appear in the standard measures of output. In addition, measures of the effect of regulation on productivity growth in construction do not reflect potential benefits which residents of the existing housing stock may obtain if regulation preserves amenities which are important to them. Potential negative effects of regulation on construction productivity are therefore only part of a much broader picture.

The current version of this paper measures construction productivity in each state by dividing Bureau of Economic Analysis (BEA) estimates of gross product originating in each state by the BEA estimate of the number of construction employees in the state. Of course, output per employee provides only a very rough index of productivity growth. Future versions of this analysis will convert the number of workers to hours, using information for hours of construction workers in each state obtained from the Census of Population and the American Community Survey; results from these Census sources will be benchmarked to BLS information on average weekly hours in construction which are available for some states. For 1997 to 2010, we use data from the Census Non-employer Statistics to measure partner and proprietor labor input in each state. The state portion of the Census of Construction provides corresponding information for 1987 and 1992. Partners and proprietors must be included because they represent an important portion of the overall construction labor force. We may perhaps also try to allow for capital intensity in the various states. We hope that the preparation of broader measures of construction productivity in each state, which allow for a greater range of inputs, will help sharpen our analysis of the effects of regulation in construction.[38] Until we can establish more broadly based estimates of productivity growth, the estimates of the impact of regulation on productivity, though potentially interesting, are still quite tentative.

In their article, Ganong and Shoag (2012) have shown that their proposed index of land use regulation is a primary driver of many of the observed patterns of urban and state economic development. This paper shows that the Ganong and Shoag index can also help to explain observed patterns of productivity growth in the construction industry. Such results provide further support for the relevance and importance of the Ganong-Shoag index of regulation.

We have briefly experimented with long-term differences, as suggested in the Griliches and Hausman (1986) analysis of panel data. Though long-term differences sometimes provide a hint that the effects of regulation are substantially stronger, on balance we have not found any consistent evidence of a greater impact.

[38] Regrettably, it does not seem feasible to measure either gross output prices or materials prices for the entire construction industry in each state.

IVB. Correcting for the Number of Illegal Immigrants.[39]

When we first considered developing measures of productivity growth in construction, commentators frequently emphasized that many illegal immigrants worked off the books, so it would be extremely difficult to establish accurate measures of labor input. Because of the potential importance of illegal aliens in construction, it is necessary to address this issue. Since the prevalence of illegal immigrants varies sharply from state to state, Section IVB evaluates the role of illegal immigrants from state data, using Pew Hispanic Center estimates of the number of illegal immigrants in each state. However, we cannot use the standard Bureau of Economic Analysis measures of construction output and labor input in each state to evaluate the presence of illegal immigrants. The BEA data on state incomes are prepared from the income side, compiled from information on labor inputs, compensation, and other factor income in each state. If the reported data on employment and earnings omit illegal immigrants, BEA estimates of output and labor input will both be understated. Subsection IVB therefore instead examines whether illegal immigrants are included in the underlying BLS data on employment and earnings in construction.

Illegal immigrants are particularly important in the construction industry. Passel (2006) showed that illegal immigrants are far more likely to work in construction rather than in most other industries. Although illegal aliens represented 4.9 percent of the total work force in 2005, they accounted for 14 percent of workers in the construction and extractive industries.[40]

Passel believes that counts of population, such as the Census of Population and the American Community Survey, generally collect information on population fairly accurately, especially when such counts are bolstered by special efforts to count hard to measure groups.[41] However, it is uncertain whether such optimism carries over to establishment surveys, such as the Census of Construction or the Current Employment Statistics, where illegal workers may be more likely to be working off establishment books.

To address whether establishment data cover illegal immigrants accurately, we compare employment count trends in population surveys and in establishment data. Part of the analysis is limited to large states because information on the presence of illegal immigrants and on construction employment is

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39 We are indebted to participants in the recent Census-Bureau of Labor Statistics Research Workshop for suggesting that we examine how the presence of illegal immigrants affects observed productivity measures.

40 Passel (2006) provides estimates of the proportion of workers in specific occupations who were illegal immigrants. Many construction occupations have very high proportions of undocumented workers. Examples are insulation workers (36%), roofers (29%), drywall installers (28%), helpers in construction trades (27%), construction laborers (25%), brick and stonemasons (25%), painters (construction and maintenance) (22%), cement masons (21%), and carpet, floor, and tile installers (20%).

41 In an interview available on the Pew Hispanic Center web site (4/17/2013) Passel explains that in his analysis he increases estimates of undocumented employment obtained from U.S. population surveys by approximately 10 to 15 percent based upon data from the Mexican Census and based upon questionnaires which ask Mexicans in the United States whether they have responded to the U.S. Census.

more reliable in large states where samples, drawn from the Current Population Survey or the American Community survey, are much larger.[42]

Assume that the annual growth rate of employment in construction in state i observed in the population data is $g_{POP,i}$. Similarly, the annual growth rate of employment observed in establishment data is $g_{EST,i}$. The number of illegal immigrants as a proportion of the population in state i in year t, as obtained from Passel's estimates, is $ILL/POP_{i,t}$.

Given this terminology, what sort of employment trends do we expect if the proportion of illegal immigrants in the population of a state, $ILL/POP_{i,t}$, increases. What is relevant for the labor market is not the rate of growth of $ILL/POP_{i,t}$, which could be very high when the illegal immigrant proportion of population increases a miniscule amount, perhaps from .0001 to .0002. What matters instead is how large the flow of illegal immigrants is as a proportion of the population. We choose to measure this effect by

$$\left[ILL/POP_{i,2} \;-\; ILL/POP_{i,1}\right]/n \tag{6}$$

that is the illegal immigrant to population ratio in state i in year 2, $ILL/POP_{i,2}$, minus this ratio in year 1, all divided by n, the number of years between years 1 and 2. Expression (6) tells us the annual amount by which the illegal immigrant to population ratio is increasing in each state. In some decades in certain states, such as California, Texas, Florida, Arizona, and Nevada, the illegal immigrant to population ratio surges rapidly. In other areas, the increase in illegal immigrants is often negligible.

We estimate the impact of the flow of illegal immigrants described in equation (6) on the measurement error in employment through a regression of the form:

$$g_{EST,i} \;=\; a \;+\; bg_{POP,i} \;+\; c[\;\left[ILL/POP_{i,2} \;-\; ILL/POP_{i,1}\right]/n\;] \tag{6b}$$

Equation (6b) first adjusts the growth of construction employment in the establishment data for the corresponding growth of employment observed in the population data. Then, after correcting for overall trends, equation (6b) examines whether unusual increases in the presence of illegal immigrants especially depress observed increases in establishment employment. What sort of increase in establishment employment might we expect If there is an increase of one percent in the ratio of illegal aliens to population, $[\left[ILL/POP_{i,2} \;-\; ILL/POP_{i,1}\right]/n\;]$? If illegal immigrants systematically work off the books and do not appear in establishment data, then the presence of illegal immigrants will distort the usual relationship between $g_{EST,i}$ and $g_{POP,i}$ and the coefficient $\hat{c}$ will be negative. On the other hand, if

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42 Passel, Jeffrey S. and Cohn, D'Vera, (2011), "Unauthorized Immigrant Population: National and State Trends, 2010" , Table A-3, presents estimates of the number of illegal immigrants in each state in 1990, 2000, 2005, 2007, and 2010. Passel, Jeffrey S. and Woodrow, Karen A. (1984), "Geographic Distribution of Undocumented Aliens Counted in the 1980 Census by State," International Migration Review (Fall 1984), pp. 642-671 provides an estimate of the number of illegal aliens in each state in 1980.

illegal immigrants are not systematically underreported in establishment data, $\hat{c}$ will be 0.[43] If the establishment data measure illegal immigrants more fully than the population data $\hat{c}$ will be positive.

We estimate equation (6b) for the decades 1980-1990, 1990-2000, ands 2000-2010, covering 144 observations in the 48 states. Somewhat to our surprise, the coefficient c is always positive and significant.[44] There is no evidence that employment in construction establishments is suppressed when illegal immigrants become much more plentiful. In fact, employment in construction establishments tends to increase even more than employment from the well-regarded population surveys.

Of course, some illegal immigrants are working off the books. However, we find no evidence that the growth of labor input in establishment data, which is central to most measures of productivity growth, is undermined by substantial increases in illegal immigration.

V. Conclusions

Measurement of construction productivity has been a difficult task for many years. As the list of references in the present paper indicates, not much progress has been made on this topic since the 1980s. Nevertheless, we are able to report some steps forward. First, reasonable deflators already exist for industries representing almost one quarter of the value of construction work. Second, the PPI has produced additional deflators which, after the 2012 Census of Construction becomes available, can be used to measure productivity growth in further portions of construction.

Measures of productivity growth in residential construction and in the construction of highways, streets, and bridges already provide some useful information. These series show little evidence of a sustained negative trend in construction productivity. It is true that productivity growth in residential construction fell sharply after the housing collapse of 2006-2008. Nevertheless, prior to the boom there is little evidence that long-term productivity growth rates were negative in residential construction. In addition, once productivity growth is corrected for cyclical fluctuations, the evidence suggests that the observed productivity trends will again be positive once housing starts revert to more normal levels. Productivity growth in highways, streets, and bridges is positive, though this probably reflects

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[43] The comparison outlined here assumes that population counts provide an accurate measure of the industry employment of illegal aliens, and can therefore serve as a valid benchmark for true employment growth. In actuality, as mentioned above, Passel believes that 10 to 15 percent of illegal aliens do not show up in population counts.

One potential limitation is that measures of industry employment are self-reported in surveys of population, and may consequently contain too much noise to be useful.

[44] The regression result for all 48 states is

$$g_{EST,i,t} = -.0078 + 1.1228 g_{POP,i,t} + 2.81 \{\frac{\left[\frac{ILL}{POP_{i,2}} - \frac{ILL}{POP_{i,1}}\right]}{n}\}$$ 48 states, 144 observations

$\bar{r}^2 = .84$ (-5.55) (25.89) (2.20) t ratios

For the 40 states with the best data:

$$g_{EST,i,t} = -.0090 + 1.1518 g_{POP,i,t} + .313 [\frac{\left[\frac{ILL}{POP_{i,2}} - \frac{ILL}{POP_{i,1}}\right]}{n}\}$$ 40 states, 120 observations

$\bar{r}^2 = .87$ (-6.17) (26.06) (2.53) t ratios

countercyclical policies which disproportionately stimulated highway construction. Overall, evidence from these three industries shows no sign of a consistent or sustained decline in productivity.

Labor shifts from high to low productivity industries contributed .44 percent a year to the decline in productivity observed from 1968 to 1978 (Allen (1985)). We found that employment shifts reduced productivity growth by 0.25 percent a year between 1987 and 2007, an amount smaller than found by Allen, but nonetheless a substantial amount. Labor shifts now represent shifts from heavy construction to contractors, whereas Allen emphasized shifts involving housing. Increases in regulation have a significant negative effect on observed productivity growth in construction, within state data which allow for differences in regulatory regimes. The implied factor share cost of regulation is estimated to be 5.7 percent of total costs for a typical observation included in the data examined. Nevertheless, the implied impact on aggregate productivity growth in construction is slight, perhaps -0.1 percent a year.

Overall, we have so far found only partial explanations for declining levels of productivity in construction. Labor shifts are still important in our analysis. Future work will expand the number of industries for which we are able to prepare useful measures, and will look at the possible impact of regulation in greater detail.

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Table 1 The Historical Record

Years	Labor Productivity $\dot{O}/O - \dot{L}/L$	MFP $\dot{A}/A$	Capital Deepening $\alpha_K(\dot{K}/K - \dot{L}/L)$	Materials Deepening $\alpha_M(\dot{M}/M - \dot{L}/L)$
1958-1967	2.0	0.5	0.1	1.1
1967-1977	-0.9	-1.3	0.1	0.3
1977-1987	-0.9	-0.3	-0.1	-0.4
1987-1997	-0.2	0.1	0.1	-0.4
1997-2007	-1.2	-1.5	0.3	0.1
1997-2010	-0.8	-1.0	0.4	-0.2

Source: Based upon equation (2). Data are obtained from unpublished Bureau of Labor Statistics listings described in Harper, Khandrika, Kinoshita and Rosenthal (2010). Materials include energy and purchased services.

To isolate the beginning of slow productivity growth in construction somewhat more sharply, between 1958 and 1963 MFP grew at a 1.3 percent rate, but declined 0.5 percent a year between 1963 and 1967.

Note: The data for 1958 to 1967 have to be checked because the decomposition implied by equation (2) does not work out accurately within these years.

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

Nominal Output per All Persons		Hour Shares		O/H
NAICS	Title	1987	2007	1987
236115	New single-family housing construction (except operative builders)	4.2%	4.5%	52
236116	New multifamily housing construction (except operative builders)	0.8%	0.5%	104
236117	New housing operative builders	3.4%	3.2%	146
236118	Residential remodelers	5.3%	5.6%	31
236210	Industrial building construction	1.7%	0.8%	58
236220	Commercial and institutional building construction	9.4%	7.0%	96
237110	Water and sewer line and related structures construction	2.5%	2.1%	49
237120	Oil and gas pipeline and related structures construction	1.3%	1.9%	32
237130	Power and communication line and related structures construction	2.1%	2.1%	37
237210	Land subdivision	1.2%	1.3%	179
237310	Highway, street, and bridge construction	5.8%	4.1%	56
237990	Other heavy and civil engineering construction	1.9%	1.0%	50
238110	Poured concrete foundation and structure contractors	2.9%	3.9%	34
238120	Structural steel and precast concrete contractors	1.0%	1.0%	43
238130	Framing contractors	2.4%	2.1%	25
238140	Masonry contractors	3.7%	2.9%	24
238150	Glass and glazing contractors	0.9%	0.7%	39
238160	Roofing contractors	3.2%	2.2%	34
238170	Siding contractors	0.8%	0.8%	27
238190	Other foundation, structure, and building exterior contractors	0.4%	0.6%	36
238210	Electrical contractors and other wiring installation contractors	9.2%	9.8%	34
238220	Plumbing, heating, and air-conditioning contractors	10.6%	11.2%	40
238290	Other building equipment contractors	1.5%	1.7%	44
238310	Drywall and insulation contractors	3.8%	4.1%	38
238320	Painting and wall covering contractors	5.1%	4.9%	18
238330	Flooring contractors	1.7%	1.7%	27
238340	Tile and terrazzo contractors	0.7%	1.4%	31
238350	Finish carpentry contractors	4.5%	3.7%	17
238390	Other building finishing contractors	0.6%	0.9%	33
238910	Site preparation contractors	4.2%	8.1%	36
238990	All other specialty trade contractors	3.3%	4.5%	30
23	Construction	100%	100%	48

Shares of hours represent the proportion of total construction hours observed in each industry. Hours include partners and proprietors.

Table 3 Index of Output Due to Shifts in Hours, 1987-2007, 1987 = 100.00.

Employment Shares From the Year	Implied Output in 1987, Using Shares of Hours Observed in That Year
1987	100.00
1992	98.18
1997	96.66
2002	96.48
2007	95.09

Source: Estimates from equation (3b) using 1987 Values of O/L and shares of hours in each of the 31 industries. Hours include partners and proprietors.

Table 4 The Effect of Regulation on Labor Productivity

Indep Variables	$\log(V/L)_{i,t}$		$\log(V/L)_{i,i} - \log(V/L)_{i,t-1}$		
	Dependent Variables				
	(1)	(2)	(3)	(4)	(5)
$\log(Reg)_{i,t}$	-.0465	-.0357			
t ratios	(-2.94)	(-3.10)			
$\log(Reg)_{i,t} - \log(Reg)_{i,t-1}$			-.0395	-.0359	-.0467
t ratios			(-1.84)	(-1.83)	(-2.17)
$(Reg)_{i,t}$					-1.5085
t ratios					(-2.89)
state dummies	Yes	Yes	Yes	No	Yes
time dummies	No	Yes	Yes	Yes	Yes
time trend	Yes	No	No	No	No
observations	1632	1632	1584	1584	1584
r^2	.63	.82	.52	.51	.52
Standard error of estimate	.02	.01	.00114	.00113	.00113

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.

Indep Variables	Dependent Variable $\log(V/L)_{i,i} - \log(V/L)_{i,t-1}$			
	(1)	(2)	(3)	
$\log(Reg)_{i,t} - \log(Reg)_{i,t-1}$	-.0359		.0067	
t ratios	(-1.83)		(.26)	
$\log(Reg)_{i,t} - \log(Reg)_{i,t-1})\,(Reg)_{i,t-1}$		-11.4482	-12.2820	-
t ratios		(-3.09)	(-2.49)	
state dummies	No	No	No	
time dummies	Yes	Yes	Yes	
time trend	No	No	No	
observations	1584	1584	1584	
r^2 adj	.4974	.4994	.4991	
Standard error of estimate	.03360	.03353	.03354	

Source: Regressions based on equation (4e).

Appendix A. NHCCI deflator and PPI deflator (BHWY) for NAICS 23731, Highway, Street, and Bridge Construction.

Table A-1 NHCCI Index and BLS PPI values for Highway, Street, and Bridge Construction.

NHCCI deflator. An output price deflator.

Year	March	June	September	December
2003	1.0000	1.0156	1.0038	.9929
2004	1.0260	1.0638	1.0849	1.0910
2005	1.1189	1.1489	1.2045	1.2429
2006	1.2727	1.3464	1.4084	1.3693
2007	1.3425	1.3118	1.2691	1.2363
2008	1.2500	1.2938	1.3521	1.2835
2009	1.1818	1.0901	1.0752	1.0410
2010	1.0683	1.0671		

BLS PPI deflator (BHWY). An input-cost based deflator. The BLS deflator is benchmarked to 1.0000 in March 2003, in order to make comparisons with the NHCCI deflator easier.

Year	March	June	September	December
2003	1.0000	1.0156	1.0000	.9929
2004	1.0417	1.0746	1.1096	1.1111
2005	1.1725	1.1966	1.2873	1.2675
2006	1.3114	1.3918	1.3589	1.3458
2007	1.3889	1.4386	1.4437	1.4817
2008	1.5629	1.7135	1.7624	1.4730
2009	1.4488	1.5256	1.5212	1.5300
2010	1.5716	1.5870		

Unemployment Rate for Construction Workers.

From Current Population Survey, series NV 0403223

Year	March	June	September	December	Annual
2003	11.8	7.9	7.6	9.3	9.3
2004	11.3	7.0	6.8	9.5	8.4
2005	10.3	5.7	5.7	8.2	7.4
2006	8.5	5.6	5.6	6.9	6.7
2007	9.0	5.9	5.8	9.4	7.4
2008	12.0	8.2	9.9	15.3	10.6
2009	21.1	17.4	17.1	22.7	19.0
2010	24.9	20.1			20.6

Pieper (1991, page 246) remarks that price indexes tend to rise more quickly than cost indexes during an economic expansion, but drop more quickly than cost indexes in contractions. In the construction of highways, streets, and bridges industry, the NHCCI price deflator increases at approximately the same rate as the BLS PPI cost deflator during the 2002 to 2006 expansion. However, during the severe downturn which occurred in 2007, and in subsequent years, the NHCCI price deflator fell much more sharply than the PPI cost deflator. Such discrepancies illustrate the need for a much broader range of price deflators in construction.

Appendix B. Development of Productivity Measures for Individual Industries.

Appendix B describes the methods through which labor productivity growth is calculated for the various industries included in construction. As indicated in Section II, the industries examined are single family residential construction, multiple family residential construction, and the construction of highways, streets, and bridges.

Appendix B contains a detailed discussion of every data source. The text reports the specific economic series from which each data item is obtained, and also describes the full and exact procedures used to construct and combine various data items. For example, on the issue of interpolation of data between Census years, Appendix B lists exactly which data source is used to interpolate each measure between Census years, and also provides the exact formula used to determine the specific values of the series in each of the intervening years.

Output.

Output of individual industries.

We start out with measures of output in each of the individual industries. We begin with the 2007 Census of Construction, the most recent final version of a Census of Construction. Table B-1 below reports information on the value of production in each of our industries in 2007; data are obtained from Table ECO723SG01 of the 2007 Census. The first column of data shows the value of output (value of business done) in the industry for establishments which report a labor compensation payroll. The second column reports the value of output (again, the value of business done) for those establishments without payroll, essentially those establishments with only self-employed workers. The third column reports total output, the sum of output in each category.

For residential construction, we have estimates of output of the second type, from establishments without payroll, for the entire residential construction industry, but similar detail is not available for the component industries. We therefore assume that the percentage increase in extra output obtained from establishments without payroll is the same, for each individual industry, as found in the aggregate data. Some of the data in the second column are therefore estimates, marked by "est". For highways, streets, and bridges actual information on output in establishments without payroll is directly available.

Primary vs. secondary products.

Like many other measures of industry production, the Census of Construction is collected from data on establishments. Some of the establishments assigned to a particular industry typically produce other products, characteristic of other industries, as well. Therefore, total production within an industry contains both products primary to that industry and secondary products, those typically produced by other industries. Within each industry, we distinguish between four categories, products primary to that industry, secondary products within construction for which we have adequate deflators (essentially

single family housing, multiple family housing, and highways, streets, and bridges), secondary products in construction without adequate deflators (all other construction products), and secondary products outside construction. In 2007, the percentage of output falling into each of these categories was:

	Primary prod	Sec prod in constr, good defl	Sec prod in constr, no defl	Outside constr
Single family	94.1	1.4	3.8	0.7
Multi family	78.8	2.8	18.0	0.4
Highways	86.1	.0	11.6	2.3

These data show that, in our three industries, most of output, from 78.8 to 94.1 percent, represents primary production. The two industries in housing each pick up a few percentage points of additional coverage from other industries with adequate deflators. The third column shows the proportion of output in the most troublesome category, other construction industries without reliable deflators. In these instances, we use the primary deflator to deflate these other types of construction output. The fourth column shows the proportion of output which falls outside the construction sector.

The third column, secondary construction products without deflators, presents the most serious problems. This represents 4 percent of output in single family homes, 18 percent in multiple family homes, and 12 percent in highways, streets, and bridges. Such proportions of un-priced secondary products are not unusual in determining output growth in many industries outside manufacturing. In these circumstances, we use the price index for primary products to price those sectors without an adequate specific deflator; the Division of Industry Productivity Studies of the Bureau of Labor Statistics has used closely similar procedures to price secondary output in many other industries.

Table B-2 illustrates the methods used to calculate secondary product prices outside construction. This table indicates the importance of secondary products outside construction for each relevant industry in 2007. Note that the proportion of primary products is calculated from the data for establishments with payroll, as reported the first column of Table B-1. Table B-2 shows that the proportion of secondary products obtained from outside construction is quite minor for each industry considered.

Nevertheless, these secondary products have to be priced by the appropriate deflator, which is different from the deflator primary to each industry. Table ECO72314 of the 2007 Census of Construction, (Construction: Industry Series: Preliminary Value of Business Done for Establishments by Kind of Business Activity: 2007) provides detailed information on exactly what sort of secondary production is produced by the establishments classified into each industry. The composition of secondary products observed outside construction in 2007 is also assumed to hold true for all other Census years.

To give a specific example, in one particular industry specific secondary products external to construction include architectural services, engineering services, rental or lease of properties, and all other business activities secondary. The all other business activities secondary category is dropped, since it is difficult to determine what activities this category includes and how to price these activities.

All the other secondary activities are used to establish a fixed weight price index, with weights based upon the observed 2007 expenditures. Each secondary product is assigned to an industry and then associated with the appropriate price index for that industry, typically obtained from the PPI.

We obtain information on how much of output falls into each of our four categories from each Census of Construction. As mentioned above, once the price of secondary products in construction for which no adequate deflator exists has been estimated, from the primary price, we then have a measure of price for four types of primary or secondary output.[45] We also have corresponding data on the value of output for each of the same four types of output. With this information on prices and on the value of output, we have sufficient data to calculate a Tornqvist index of output which covers all primary or secondary production within each industry. This Tornqvist index is our measure of output in each industry.

Allocating the output of for-sale builders to single and multiple family construction.

In 2007 the Census of Construction reported separate data for NAICS industry 236115, single family residential construction, industry 236116 multiple family construction, and industry 236117, for-sale builders. In 2002, NAICS 236117 was called new housing operative builders, but the content of this industry was apparently quite similar to the industry boundaries observed in 2007. However, in the 1997 Census, and in prior years, NAICS 236117 did not exist, and its contents were instead included in NAICS 236115 or 236116. Table B-3 shows the relevant bridge table from the 2002 Economic Census.[46] On the basis of this bridge table, 98.00% of NAICS 236117 output is assigned to single family residential construction, and 2.00% of output is assigned to multiple family residential construction. As the bridge table also indicates, all of single family construction remains in that category, though the NAICS number changes, and all of multiple family construction also remains in that category.

Deflators.

Single family residential construction.

This portion of the discussion considers and presents the specific deflators used to deflate each of the output series described above. Each of the deflators considered is converted to an index value of 100.0 in the year 1987, to ensure that output is measured consistently across different types of construction. The most influential deflator used, which represents the largest volume of construction activity, is the deflator for single-family residential construction. This series has a long history, dating back to Musgrave (1969).

[45] As in the text above, the four categories of output considered are primary products, secondary products in construction where an adequate deflator exists, secondary products in construction with no adequate deflators, and secondary products outside construction.

[46] The specific reference is 2002 Economic Census, Bridge Between 2002 NAICS and 1997 NAICS for All Sectors. Operative builders are allocated to the single and multiple family categories, but the residential remodelers also included in the bridge table are not included in any of our measures.

All information on the price index for single family residential construction is obtained from the Bureau of the Census web page on Construction Price Indexes. We select the Census series on the price index for houses under construction. The alternative index for new single family houses sold is inappropriate for our purposes because it includes the value of the lot and certain other costs outside the bounds of construction.

Among the various Census price series for houses under construction, we adopt the annual series on the Fisher price deflator. As the discussion of General Information on the Census web page indicates, the Fisher Ideal Index is appropriate to measure the value of today's homes being constructed in constant dollars. Specifically "This index can be used as a price deflator in determining the constant dollar value of today's output of houses under construction, which is included in the Gross Domestic Product."

The portion of the Census web page dealing with the Details of the Regression Models explains how the regression estimates correct for items such as square footage, the number of bedrooms or bathrooms, the presence or nature of a garage, and the characteristics of the heating and cooling system. House characteristics also include several geographic variables.

The Census web page provides specific values of the Fisher Ideal Index for single family residential construction in each year. Table B-4 reports the annual price index used for every year between 1987 and 2012. This is the specific series used to deflate single family residential construction expenditures. 2005 is the base year for this price index.

Single family constant quality construction price indexes.

The Census Bureau also reports price indexes for single family construction using a constant quality of houses, namely the specific characteristics of new houses actually produced in a particular year. We utilize a version of these data which reports both the average sales price of houses actually sold and the average sales price of the typical 1996 house. The information on a 1996 base is obtained from previous versions of the Census web page on Construction Price Indexes.

Since the constant quality index considers price trends for houses in a fixed base year, it is a Laspeyres index rather than the Fisher Ideal Index summarized in Table B-4. Table B-5 lists the average price of all houses and the price of houses with fixed 1996 characteristics. Dividing the average price of all houses by the price of houses with fixed 1996 characteristics, we obtain a measure of the quality improvement in new single family homes. Figure 1 includes a line representing this quality improvement index.

Multiple family residential construction deflator.

de Leeuw (1993) introduced the output deflator used for multiple family residential construction. Like the single family deflator, the multiple family deflator is a hedonic index. The index corrects for such characteristics as square feet per unit, the number of units in the project, bathrooms, bedrooms, the presence of parking structures, air conditioning, and certain geographic variables.

We obtain values of the de Leeuw deflator from Table 5.4.4 of the National Income and Product Accounts, which reports information on Price Indexes for Private Fixed Investment in Structures by Type. We use the row entitled Residential Multiple Family Structures. As is the case with all the deflators, this series is converted to represent an index value of 100.0 in the base year 1987. Table B-6 reports the specific value of the multiple family output price deflator in each relevant year.

Highway, street, and bridge construction.

Table A-1 in Appendix A has already reported values for the National Highway Construction Cost Index from 2003 to 2010. The Federal Highway Administration reports these index values quarterly; we use the arithmetic average of the four quarterly values to calculate the overall index for each year. (Since the NHCCI begins only in 2003, we use the older Bid Price Index to determine price increases between 2002 and 2003. The Bid Price Index was 47.9 in 2002 and 49.8 in 2003.

Interpolation of Output Between Census Years.

The central output measures discussed above refer to Census of Construction years. Once these Census of Construction data have been obtained, we interpolate in intervening years using information from another Census series, the annual Value of Construction Put In Place data. The Census provides the Value of Construction data in classifications which are not expressed in terms of NAICS industries, and there is no established concordance between the Value in Place data and the NAICS industries described in the Census of Construction. Despite these limitations, we select the closest analogue from the Value of Construction data and assign this to each of the Census of Construction industries we are considering.

For single family and multiple family residential construction, we obtain information from the Construction Spending web page of the Census. From this Census page, we select Historical Data, and then, from the Historical Value Put in Place category, we select Private. This provides a table on Annual Value of Private Construction Put in Place. From this table, under the category Residential, we select annual information on Private Residential Expenditures in both the New single-family and New multiple-family categories. These two series are used to interpolate output between Census years in each of these categories.

For information on annual expenditures on highways, streets, and bridges, we return to the Census Construction Spending Page and to the Historical Data option. This time, we select Total data, and from the table on Annual Value of Construction Put in Place, under the category Public, we select the Highway and Street expenditures series. This is the series used to interpolate highway expenditures between Census years.

Once we have obtained annual information on output in the relevant category for every year from the Value Put in Place Series, we calculate the ratio of the value of output from the Census of Construction to the value of the selected Value Put in Place proxy for each of two adjoining Census years. We then interpolate this proportion linearly. Given the appropriate ratio, we multiply the annual Value Put in

Place data by the interpolated ratio to estimate output in each year. More specifically, for years in which there are five years between Censuses, the current procedure is:

$$\left(\frac{\widehat{Census}}{ValuePutinPlace}\right)_x = \left(\frac{Census}{ValuePutinPlace}\right)_{Censusyear1} + \frac{x}{5}\left\{\left(\frac{Census}{ValuePutinPlace}\right)_{Censusyear2} - \left(\frac{Census}{ValuePutinPlace}\right)_{Censusyear1}\right\}$$

$$x = 1,2,3,4$$

Once the ratio of Census of Construction output to Value Put in Place is estimated for each year, then:

$$\widehat{Census}_x = \left(\frac{\widehat{Census}}{ValuePutinPlace}\right)_x ValuePutinPlace_x$$

that is the estimated value of construction output in any year x is determined by taking the estimated ratio of Census of Construction output to Value Put in Place output for that year, and multiplying by the actual Value Put in Place output observed in that year.

Labor Input.

Labor input consists of the hours of paid employees plus the hours of self-employed workers, such as partners and proprietors. We describe the calculations used to produce each of these elements of labor input in turn.

Paid Employees.

The main measure of the number of paid employees in each industry in construction is obtained from the Census of Construction, which provides such information every five years. The 2007 Census of Construction reports employment in each construction industry in Table ECO72311. The 1987 and 1992 censuses were conducted on a Standard Industrial Classification (SIC) basis, while 1997 was reported on a 1997 NAICS basis. We used the Paid Employment conversion ratios listed in the 1997 Economic Census and the 2002 Economic Census to convert the data into a consistent series based upon the 2002/2007 NAICS. In addition to total employment, we also collected corresponding measures of the number of construction workers and of the number of other workers in each industry.

For intervening years between the Census of Construction, we interpolate employment on the basis of annual data on employment obtained from the Bureau of Labor Statistics Current Employment Statistics (CES).[47] The CES also provides corresponding information on production worker employment. The method of interpolation is quite similar to that conducted for output, and is discussed below.

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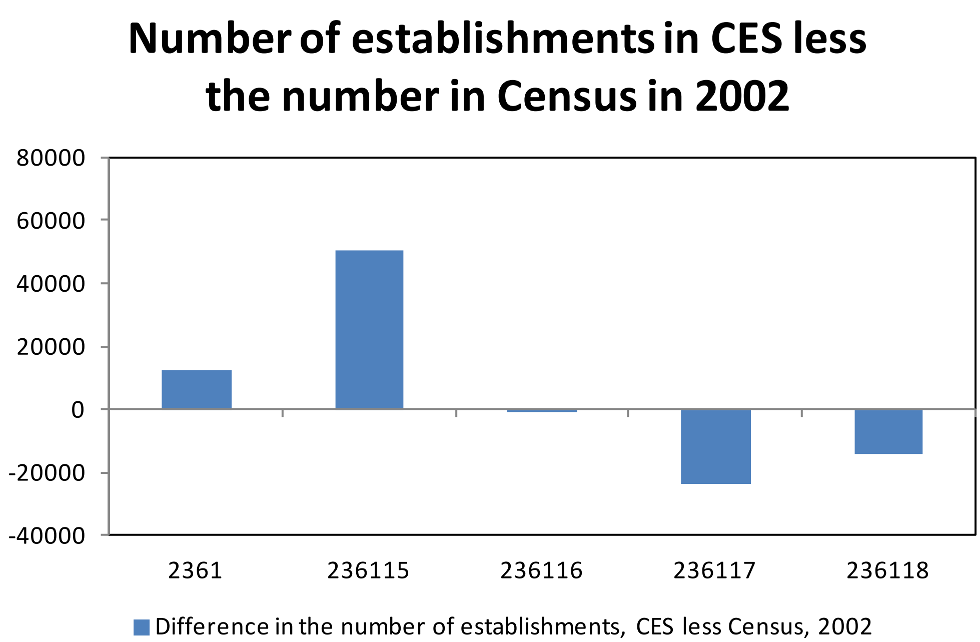
47 As remarked in the text of our paper, the Census of Construction is selected as the primary source of information on labor input because the Census data on employment are consistent with Census output data.

As was the case for output, employment data for NAICS 236117, operative builders, has to be allocated to single and multiple family residential construction. The employment ratios listed in Table B-3 are used for this purpose. The data on residential construction illustrate how information from the Census and from the Current Employment Statistics can diverge. For example in residential construction in general, NAIC 2361, in the 2002 the Census reported almost as many establishments as the CES. However, in NAICS 236115, single family construction, the CES had many more establishments. Conversely, in NAICS 236117, operative builders, the Census had more establishments than the CES. Fortunately, in this case the differences became more minor once operative builders were allocated to single or multiple family construction.



Hours of paid employees.

From 2007 onwards, the Current Employment Statistics reports information on the average number of hours for both all employees and for production workers. Since we also know the number of employees in each category, average weekly hours of nonproduction workers can simply be calculated as:

$$AWH_{NPR} = [(Employees * AWH_{EMP}) - (Production\,Workers * AWH_{PW})]\,/Nonprod\,Workers$$

AWH represents average weekly hours for non-production workers (NPW), all employees (EMP), and production workers (PW) respectively. Clearly, it is a simple matter to determine average weekly hours for each group from the available data.

Prior to 2007 the Current Employment Statistics reported average weekly hours for production workers, but not for total employees. The only information on hours of nonproduction workers comes from the BLS Current Population Survey (CPS), from which the Division of Industry Productivity Studies

has calculated the ratio of nonproduction average weekly hours to production worker average weekly hours. This information is available annually. However, it refers only to total construction; no industry detail is available. Using this information we first estimate nonproduction worker hours in each construction industry i in each year prior to 2007 from:

$$\frac{NPAWH_{i,t}}{NPAWH_{i,07}} = \frac{PWAWH_{i,t}}{PWAWH_{i,07}} \frac{CPS_t}{CPS_{07}}$$

in which average weekly hours of nonproduction workers in industry i change from their 2007 level either because average weekly hours of production workers in industry i change or the overall ratio of nonproduction worker hours to production worker hours, obtained from the CPS as one single annual measure for all of construction in year t, changes. Finally, measures created through the method described above have a discontinuity between the years of 2006 and 2007, so we benchmark the series on average weekly hours of nonproduction workers to its 2007 level, and chain the proposed index backwards.[48] Once average weekly hours are known, we multiply the number of workers times average weekly hours times 52 weeks to find total hours worked in each year.

Number of partners and proprietors.

The main source of information on the number of self-employed workers in each industry is the data on partners and proprietors (P&Ps) published in the Census of Construction. Each Census year, the Census of Construction provides, in the Subject Series, a volume on Legal Form of Organization and Type of Operation. These volumes report the number of establishments with partners or proprietors, with separate reports for those establishments with and without payroll. This Census information forms the basis for our measures of the number of partners and proprietors in each industry. Note that these measures of self-employment are fully consistent with our measures of paid employment and of output, since all three series are drawn directly from the Census of Construction.

In calculating self-employment, we count the number of self-employed individuals as the number of establishments run by proprietors plus the number of establishments operated by partnerships multiplied by the number of partners per partnership. The Internal Revenue Service Statistics of Income, Tax Stats, Partnership Statistics by Sector or Industry, Table 1, provides information on the number of partners per partnership in construction. The data show that in construction there are approximately 2.9 partners per partnership, although the specific value differs somewhat across years.

In the 1987 and 1992 Census of Construction, Table 1 of the Subject Report on Legal Form of Organization lists the number of establishments run by partners and proprietors separately for

[48] A discontinuity occurs because in 2007 we have actual information on weekly hours for nonproduction workers in each industry, whereas in 2006 and prior years we only have estimates of average weekly nonproduction hours as predicted from production worker hours and the nonproduction worker/production worker hours ratio for all of construction. By linking to the 2007 value and chaining for previous years we allow for industry differences in the length of the nonproduction worker work week, as observed in the 2007 data. The linkage procedure builds these industry differences into the data base for earlier years.

establishments with and without payroll. However, Table 1 provides detail only at the three-digit level of the SIC. Table 2 reports further industry detail, but only for establishments with payroll. Therefore, in 1987 and 1992 we allocate the three-digit information on P&Ps by assuming that the same proportions already available for those establishments with payroll also hold true for establishments without payroll. With this allocation procedure, and with changes to the NAICS structure similar to those discussed above, we have complete data on the number of partners and proprietors in each industry in each Census year.[49]

The next task is to determine partner and proprietor employment for each year between Census years. The Census Bureau Non-Employer Statistics series provides such information annually beginning in 1997, but only for four-digit NAICS industries. We use the Non-Employer Statistics annual data on partners and on proprietors to allocate P&P self-employment between 1997 and 2010. Prior to 1997, the Non-Employer data are not available. Therefore, between the 1987 and 1992 Censuses, and the 1992 and 1997 Censuses, we benchmark self-employment to the corresponding series for paid employees in each industry.

Partner and proprietor hours.

The only source of information on average weekly hours of partners and proprietors in construction is the Current Population Survey (CPS). The CPS provides no detail on individual industries in construction, but simply reports average weekly hours of partners and proprietors for all of construction.[50] We assume that the CPS data on average weekly hours of partners and proprietors can directly be applied to each individual industry within construction. Multiplying the number of P&P by their average weekly hours times 52 provides the total number of hours worked by self-employed workers within each industry in construction during every year.

Total Hours and Labor Productivity.

Once we have calculated total hours for both paid employees and partners and proprietors we add the two types of labor together to obtain a measure of the total hours utilized in each industry in each year. The number of hours is converted to index form with the value of 100.00 in the base year 1987. Output measures are similarly converted to index form with the base year 1987. We then divide the output index by the index of total hours to obtain comparable index values of output per hour, or labor productivity, within each industry in each year.

Interpolating Estimates of Labor Inputs Between Census Years.

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[49] When NAICS industries change, or when operative builders are allocated to single and multiple family residential construction, we consistently use the employment bridges to assign partners and proprietors to the appropriate industry.

[50] From 1982 to 1984 the CPS briefly reported information on P&P average weekly hours in several different fields of construction. These data are not a sufficient basis to develop measures of P&P hours for the different industries in construction.

The last topic to be discussed in this data section is the interpolation of labor inputs between Census years. The Current Employment Statistics (CES) provides annual data on the number of employees and the number of production workers in each detailed construction industry for each year from 1987 forwards. We create benchmark ratios by calculating the ratio of Census employees to CES employees in each Census year. These ratios are interpolated linearly between each pair of adjacent Census years. Once the appropriate Census/CES employment ratio has been determined, we multiply this by CES employment in each year to obtain an employment series consistent with the Census data. A similar benchmarking technique is used to distribute Census construction workers to individual industries in each intervening year in proportion to CES data on the number of production workers in each detailed construction industry. The specific equations used to interpolate labor input in each intervening year are similar to those described in the discussion of output above.

Table B-1 Value of Business Done by Construction Industry, 2007, in millions of dollars.

Industry	Value of Business for Establishments With: Payroll	No Payroll	Implied Total Value of Business
All Residential	358562.4	50920.6	
Single Family	90006.2	12782.1 est	102788.2
Multiple Family	34702.9	4928.3 est	39631.2
For-Sale Builders	181371.2	25757.1 est	207128.4
Remodelers	52482.1		
Highways, streets	106598.3	472.7	107071.0

Source: 2007 Census of Construction, Table ECO723SG01, Construction: General Summary: Detailed Statistics for Establishments: 2007.

Table B-1 does not provide detailed data on the value of business done by residential remodelers because this is not one of the industries considered.

Table B-2 Value of Business Done, Value of Construction Receipts, and Value of Other Business Receipts, by Industry, 2007 (in millions of dollars).

Industry	Value of Business	Value of Construction	Value of Other Business	Secondary Outside Const
Single Family	90006.2	89282.7	723.5	0.8%
Multiple Family	34702.9	34559.4	143.5	0.4%
For-Sale Builders	181371.2	180056.8	1314.4	0.7%
Highways	106598.3	104256.2	2342.2	2.2%

Source: 2007 Census of Construction, Table ECO72314, Construction: Industry Series: Preliminary Value of Business Done for Establishments by Kind of Business Activity: 2007.

Table B-3 Bridge Table Allocating NAICS 236117 to Its Single and Multiple Family Components.

2002 NAICS	1997 NAICS	Establishment Ratios	Value of Business Ratios	Payroll Ratios	Employees Ratios
236115	233210	100%	100%	100%	100%
236116	233220	100%	100%	100%	100%
236117	233210	98.28%	98.00%	96.97%	96.68%
236117	233220	1.72%	2.00%	3.03%	3.32%

Source: 2002 Census of Construction, Table 1, Bridge Between 2002 NAICS and 1997 NAICS.

Note that NAICS 236118, residential remodelers, was also allocated to NAICS 233210, single family construction and NAICS 233220, multiple family construction in 1997. However, we do not include residential remodelers in our single and multiple family measures to make sure that the output measures are aligned with the available price indices, which refer only to new construction. As is standard in the use of most bridge tables, residential remodelers are assumed to account for the same proportion of output in NAICS 2333210 and NAICS 233220 in 1987-1996 as they do in 1997.

Table B-4 Fisher Ideal Index for Single Family Residential Construction, 1987-2012.

1987	52.7	1998	72.5	2009	98.1
1988	54.5	1999	72.7	2010	96.4
1989	56.4	2000	75.9	2011	97.4
1990	58.0	2001	79.7	2012	98.4
1991	58.2	2002	81.7		
1992	58.9	2003	85.9		
1993	61.8	2004	93.1		
1994	64.6	2005	100.0		
1995	67.3	2006	106.0		
1996	68.6	2007	107.0		
1997	70.6	2008	103.3		

Source: Bureau of the Census web page on Construction Price Indexes. 2005 = 100.0.

Table B-5 Average Prices of All Single Family New Houses, and Price of Houses with Fixed 1996 Characteristics, 1987-2007, in dollars.

Year	Price of All Houses	Price of a House With 1996 Characteristics
1987	127200	128800
1988	138300	133600
1989	148800	138900
1990	149800	141600
1991	147200	143400
1992	144100	145300
1993	147700	151600
1994	154500	158900
1995	158700	163400
1996	166400	166400
1997	176200	171200
1998	181900	175600
1999	195600	184200
2000	207000	192000
2001	213200	198800
2002	228700	207700
2003	246300	219500
2004	274500	236100
2005	297000	254800
2006	305900	264900
2007	311600	266400

Source: Prior versions of the Census web page on Construction Price Indexes.

Table B-6 Price Index for Residential Multifamily Structures (2005 = 100.0).

Year	Index Value	Year	Index Value	Year	Index Value
1987	56.423	1997	68.374	2007	116.675
1988	57.928	1998	71.868	2008	121.499
1989	58.090	1999	75.422	2009	124.750
1990	57.467	2000	78.624	2010	121.700
1991	58.580	2001	80.997	2011	124.227
1992	59.687	2002	82.932		
1993	60.996	2003	85.338		
1994	61.620	2004	90.620		
1995	63.157	2005	100.000		
1996	64.898	2006	109.85		

Source: Bureau of Economic Analysis, National Income and Product Accounts, Table 5.4.4.