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WHY CONSTRUCTION INDUSTRY PRODUCTIVITY IS DECLINING

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ABSTRACT

According to unpublished data compiled by BLS, productivity in the construction industry reached a peak in 1968 and, except for a brief and small upturn between 1974 and 1976, has been falling ever since. This paper examines the sources of this productivity decline between 1968 and 1978 by estimating a production function to assign weights to various factors responsible for productivity change and deriving a new price deflator for construction which does not rely on labor or material cost indexes, thus eliminating a systematic bias toward overstating the rate of growth of prices.

The production function analysis indicates that productivity should have declined by 8.8 percent between 1968 and 1978, representing 41 percent of the observed decline. The biggest factor in this decline was the reduction in skilled labor intensity resulting from a shift in the mix of output from large scale commercial, industrial, and institutional projects to single-family houses. Other important factors include declines in the average number of employees per establishment, capital-labor ratio, percent union, and the average age of workers. The difference between the official deflator and the new deflator proposed here accounts for an additional 51 percent of the reported productivity decline, leaving only 8 percent of the decline unexplained.

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I. Introduction

According to unpublished data compiled by the Bureau of Labor Statistics (BLS), productivity in the construction industry reached a peak in 1968 and, except for a brief and small upturn between 1974 and 1976, has been falling ever since. Real output (value added) per hour in construction fell at an annual rate of 2.4 percent between 1968 and 1978 (see Table 1). In contrast, between 1950 and 1968 real output per hour rose at an annual rate of 2.2 percent. This amounts to a decline in the annual average rate of productivity growth of 4.6 percentage points. When productivity is measured in terms of output per employee, the decline in the productivity growth rate is 4.5 percentage points.

Because construction accounts for 5 percent of employment and output, this productivity decline has had a nonnegligible effect on the decline in aggregate productivity growth over this period. The annual growth rate of output per hour in the nonfarm business sector dropped from 2.4 percent between 1950 and 1968 to 1.5 percent between 1968 and 1978. If productivity growth in construction had continued at the same rate as in the 1950-1968 period, aggregate productivity growth would have fallen to 1.7 percent. Viewed in this way, roughly 22 percent of the decline in aggregate productivity growth over these periods can be attributed to the construction industry.[1]

A study by H. Kemble Stokes, Jr. (1981) of the U.S. Department of Commerce is, to my knowledge, the only careful analysis of the sources of the productivity decline in construction.

Table 1. Average annual growth rates of productivity, output, and inputs in construction, 1950-1968 and 1968-1978

	1950-1968	1968-1978	Change between 1950-1968 and 1968-1978
1. Real output per hour	2.2	-2.4	-4.6
2. Real output per employee	2.0	-2.5	-4.5
3. Real output	3.8	0.3	-3.5
4. Nominal output	9.5	6.6	-2.9
5. Labor hours	1.5	2.8	1.3
6. Employment	1.7	2.9	1.2
7. Net stock of fixed capital, current dollars	6.8	2.4	-4.4

Sources: Lines 1-6, unpublished data, Bureau of Labor Statistics.

Line 7, unpublished data, American Productivity Center.

Stokes found slower growth in capital per worker responsible for a 0.8 percent decline in the growth rate of productivity. No other factor accounted for more than 0.2 percentage points, and all factors combined accounted for a mere one-fourth of the change in the growth rate. Stokes' analysis implies productivity should have continued to grow at a slower rate rather than declining.

A more recent study by Schriver and Bowlby (forthcoming) examines changes in real unit cost in building construction (excluding residential structures with less than five units) between 1972 and 1982. They obtain these estimates through hedonic price equations that have been deflated into 1972 dollars with a weighted average of a price index for single-family homes and the cost indexes published by the Turner Construction Company and American Appraisal Company. They find that changes in the mix of output within building construction explain over one-third of the observed increase in building costs.

This paper takes two new approaches to explaining this decline in productivity. First, instead of using the conventional growth accounting framework, I use production function estimates to assign weights to various factors responsible for productivity change. This approach allows me to estimate the impact of two variables that generally are excluded in the growth accounting approach: the extent of unionization and the mix of output. It also allows me to test whether the weight given by Stokes to changes in the capital-labor ratio is appropriate.

Second, my analysis attempts to confront directly the issues involved with measuring output changes over time in construction. The price deflator used in the national income accounts is upwardly biased because it is still largely based on cost data for labor and materials rather than on prices of actual projects. I derive a new deflator for nonresidential building construction based largely upon F. W. Dodge data on the value and square footage of various types of projects. Since the appropriateness of this deflator depends upon the assumption that square footage is a reasonable proxy for output, I use micro data on contract amounts, square footage, and building characteristics for four samples of buildings to assess its validity.

II. Production Function Estimates

To determine the impact of the capital-labor ratio, economies of scale, labor quality, percent union, composition of output, and distribution of construction projects across regions, I estimated a Cobb-Douglas production function over data from the 1972 and 1977 Censuses of Construction Industries (CCI). There is a separate observation for each state in each year. This level of aggregation was selected because it allowed me to estimate the effect of interstate variations in the compositon of output on measured productivity. The dependent variable is the log of the ratio of output per employee. The output measure is value added divided by an employment-weighted average of the cross-section Dodge Cost Index for all cities in each state (New York City in 1972=100). Since this index is based heavily on union wages, this procedure introduces downward bias in the union coefficient if union wages are correlated with productivity, as discussed in Allen (1984).

The independent variables are the ratio of capital input to employment, the ratio of employment to establishments, predicted earnings based on the occupational distribution in each state (all of the above in logs), percent union, three region dummies, and the ratios of receipts from three different types of construction (single-family homes, office and industrial buildings, and educational and hospital buildings) to total construction receipts.[2] Capital input equals the sum of (1) gross capital stock at year end divided by 15.15 (the average economic life of capital in construction, as reported in Allen (1984)) and (2) rental payments for capital. Values for 1977 are deflated to 1972 dollars with a weighted average of the implicit price deflators from the national income accounts, using the shares of each type of capital in 1954-1959 total capital expenditures for construction reported by Boddy and Gort (1971) as weights. Data on the occupational distribution by states and mean national earnings by occupation come from the 1970 Census of Population. Percent union for 1972 comes from the May 1973-75 Current Population Survey micro files; for 1977, the May 1977-78 files. All other variables come from CCI.

Cross section estimates for 1972 and 1977 and pooled time series-cross section estimates for both years are reported in Table 2. The F-statistic for the hypothesis that all coefficients except the intercept are identical in both years was 0.703, well below the 95 percent critical value. Since I cannot reject the hypothesis that all coefficients except the intercept are the same, I will use the pooled time series-cross section results to analyze the sources of the productivity decline in construction.

The results are fairly close to those obtained in Allen (1984) for 1972 over the same data (except for a different labor quality variable) aggregated by two-digit SIC and states or regions. The capital-labor coefficient is larger (.24 versus .19), while the percent union coefficient is smaller (.12 versus .16). The capital-labor ratio coefficient is very close to the .20 assumption used by Stokes. The only major difference between the results in Table 2 and my earlier study is the employees per establishment coefficient. Whereas my earlier estimates showed no economies of scale, the results in Table 2 show a strong positive correlation between employees per establishment and productivity. This seems to have resulted from the different ways in which the samples were aggregated.

Interstate differences in the composition of construction output are strongly correlated with measured productivity. A ten percentage point increase in the share of single-family homes is associated with a 2.7 percent decrease in productivity. The same

Table 2. Coefficients and standard errors of construction industry production functions

	1972	1977	Pooled 1972 and 1977
Intercept	-4.874 (6.285)	-2.838 (5.615)	-6.446 (3.652)
Log (K/L)	.212 (.043)	.340 (.062)	.241 (.032)
Log (L/establishments)	.174 (.058)	.138 (.051)	.184 (.034)
Labor quality factor	.815 (.689)	.602 (.611)	.994 (.399)
Percent union	.122 (.100)	.095 (.062)	.118 (.051)
Northeast	.038 (.034)	-.012 (.029)	.027 (.020)
North Central	.064 (.031)	.029 (.026)	.052 (.019)
West	.104 (.038)	.031 (.036)	.075 (.024)
Percent single-family homes	-.188 (.201)	-.324 (.180)	-.267 (.129)
Percent office and industrial buildings	.334 (.224)	.474 (.242)	.338 (.152)
Percent educational and hospital buildings	.646 (.451)	.188 (.444)	.449 (.260)
1977 dummy	--	--	-.082 (.012)
R^2	.804	.828	.850
N	51	51	102

Note: The dependent variable is value added per employee deflated by the Dodge Cost Index.

increase in the share of office and industrial buildings is associated with a 3.4 percent increase in productivity; educational and hospital buildings, a 4.5 percent increase.

The coefficients of the composition of output variables lend themselves to two interpretations. One possibility is that these variables reflect unobserved differences in the quality of inputs across states. Skilled labor is used more intensively in large commercial, educational, and hospital projects than in the construction of single-family homes. According to a series of recent BLS Labor and Material Requirements Surveys, the percentage of laborer, helper, and tender hours in total onsite hours in private single-family home construction was 28 percent in 1969. The corresponding figures for commercial office building construction in 1972 and 1973 was 23 percent; for elementary and secondary school construction in 1972, 22 percent; for hospital and nursing home construction in 1975, 21 percent.[3] In addition, within narrow occupational categories, there are also important, but usually not observable (to the person analyzing the data) differences in labor quality between single-family home and commercial construction. The job of a 45-year-old electrician with a high school degree on a commercial project is usually much more complex than that of a person with identical observable characteristics on a single-family residential project. Accordingly, many unions have now established separate, lower rates for residential work to compensate for these differences.

Alternatively, these coefficients could indicate differences in rates of return or capital intensity. To check this interpretation, interaction terms between the composition of output variables and the capital-labor ratio were added to the model. The coefficients of the interaction terms, available upon request, were either statistically insignificant from zero or outlandishly large. Thus, the unobserved labor quality interpretation seems most appropriate.

III. Sources of the 1968-1978 Productivity Decline

The impact of six possible sources of declining productivity can be examined with the regression estimates: capital-labor ratio, economies of scale, labor quality, unionization, changes in the location of construction activity, and changes in the mix of construction output. This section discusses how 1968 and 1978 values for each of these factors were obtained and summarizes their net effect on productivity.

a. Capital-labor ratio. The capital-labor ratio coefficient for the pooled 1972 and 1977 sample is very close to Stokes' assumption on capital's share. Thus, any differences between Stokes' and my estimate of the impact of the capital-labor ratio must arise from differences in data sources and in how capital services are derived from capital stock data. Two different sources of capital input data were examined: the Department of Commerce Bureau of Industrial Economics's (BIE) series on gross stocks of equipment and structures (book value in constant dollars) and the American Productivity Center's (APC) index of capital input.[4] The BIE series (a revised and extended version of that used by Stokes) was converted into an annual flow of services measure by assuming a 5 percent interest rate and 17- and 40-year lengths of life for structures and equipment, respectively.[5] This approach is identical to that used by Griliches (1967). Separate flow measures for equipment and structures were derived. Since the stock of structures grew much more rapidly than the stock of equipment (8.8 percent per year as opposed to a 3.6 percent per year), the service flow measure grows by less than the combined stock of structures and equipment (4.3 versus 4.9 percent per year). The APC series compiled by John Kendrick and Elliot Grossman provides no breakdown between equipment and structures. The APC measure grew at the much slower rate of 2.4 percent per year. To obtain capital-labor ratios, both capital measures were divided by BLS's unpublished measure of labor hours.

The net effect of changes in the capital-labor ratio on productivity is very sensitive to which measure is used. According to the BIE measure, the capital-labor ratio actually grew by 15.6 percent between 1968 and 1978, resulting in a 3.5 percent increase in productivity. In contrast, there is a 3.8 percent decline in the APC capital-labor ratio, resulting in 0.9 percent fall in productivity.

Which estimate is more credible? The APC measure is more consistent with the change in the capital stock data reported in the 1972 and 1977 CCI (no capital stock data are reported in the

1967 CCI, making comparisons over a longer period impossible). The nominal capital stock in the CCI increased by 59 percent over this period. The price deflator used in Table 2 for capital rose by 53 percent, implying a real increase of 3.7 percent. The BIE measure rose at the much higher rate of 25.8 percent. In contrast, the APC measure rose by 7.4 percent, a rate much closer to that observed in the CCI. The BIE capital stock series is also based upon a much less rapid depreciation schedule than the APC series.[6] Assuming that the value of much of the industry's capital depreciated very rapidly as a result of the oil price increases in the 1970s, the APC measure better reflects economic reality.

b. <u>Economies of scale.</u> In this report I use data from the 1967 and 1977 CCI on number of establishments with payrolls. To make the BLS labor hours measure consistent with these data, I use values of hours for 1967 and 1977 as well. Presumably, the 1967-1977 changes closely resemble the 1968-1978 changes.

The number of labor hours provided by the average establishment shrank considerably over this period. The number of establishments grew by 30.2 percent, while labor hours grew at a much slower rate of 19.5 percent. This resulted in an 8.1 percent decrease in average hours per establishment. The regression model implies that this decline in average establishment size resulted in a 1.6 percent decline in productivity.

c. <u>Labor quality.</u> The predicted effect of labor quality in the regression results (.994) is almost identical to that of labor hours (.943=1+.184-.241), implying changes in the labor quality measure have the same effect as changes in labor hours. Although differences in the occupational structure across states were used to estimate the regression model, there is little reason to believe changes in this variable will tell us very much about changes in the quality of labor services over time. Changes in the quality of labor within each occupation resulting from demographic shifts and schooling are likely to be much greater than the quality change implied by occupational shifts over such a short period. Hence, I will focus on changes in the demographic and educational mix of the labor force.

Stokes reports the distribution of employment by sex and two age groups (16-24 and 25 and over for 1968 and 1978). A labor quality index is obtained by weighting these frequencies by the corresponding value of median usual 1967 weekly earnings for the United States (also reported in Stokes). This index falls by 3.2 percent, implying a 3.1 (=.943 x 3.2) percent decline in productivity.

The median level of schooling for men increased from 11.3 to 12.3 years between 1968 and 1978. To evaluate the effect of this increase on productivity in construction, I use my wage equation estimates (Allen (1984)). These results imply a 2.6 percent increase in predicted earnings and a 2.4 percent increase in productivity. The net effect of changes in both demographics and schooling is a 0.7 percent decline in productivity.

d. Percent union. The proportion of employees belonging to unions in construction in 1978 is 32 percent, a figure derived from the public use tape of the May 1978 CPS. No such figure is available for 1968. To derive an estimate of percent union for that year, I assume the proportional change in percent union equals the ratio of the proportional change in union membership to the proportional change in employment. The rate of change in union membership is derived from unpublished data compiled by Neil Sheflin and Leo Troy of Rutgers University. Membership figures for each of the 16 building trades unions were adjusted for membership outside the United States and in other industries. The employment data are unpublished BLS estimates.

Adjusted union membership grew from 2.16 million in 1968 to 2.35 million in 1978, an 8.8 percent increase. During the same period, employment grew from 4.05 to 5.38 million, a 32.8 percent increase. This implies percent union in 1978 was 81.9 percent of percent union in 1968 and sets percent union in 1968 at 39. A decline in percent union of 7 percentage points implies a 0.8 percent decline in productivity. There is good reason to believe this estimate is too conservative. As I argue in Allen (1984), the use of an output deflator based heavily on union wages biases the union coefficient downward. The union coefficient in Allen (1984) increased by .05 when a deflator based on hedonic housing price equations was used instead. If the union coefficients in Table 2 were increased by the same amount, the decline in unionization would result in a 1.2 percent decline in productivity.

e. Regional shifts. The Northeast and North Central regions lost a sizable share of industry output to the South and West. The Northeast's share of employment fell from 22.8 percent in 1968 to 16.2 percent in 1978. The decline for the North Central region was somewhat smaller, 26.1 to 24.0 percent. The West posted the biggest gain, increasing from 15.4 to 20.1 percent, while the South's share increased from 35.6 to 39.7 percent.

Despite these sizable shifts, changes in the location of construction activity did not contribute to the productivity decline. Although the declines in the shares of the Northeast and North Central regions are associated with a 0.3 percent decline in productivity, this is offset by the 0.4 percent increase in productivity associated with the increase in the share of the West. Regional shifts thus resulted in a 0.1 percent increase in productivity.[7]

f. Mix of output. Table 3 summarizes the change in the mix of construction output across different types of projects between the 1967 and 1977 CCI. Over this period there was a slight shift from building to nonbuilding construction, but the largest changes took place within the building sector. The biggest change in the mix of output was the increase in the share of single-family homes from 20 to 26 percent. This was accompanied by substantial declines in the shares of industrial and educational buildings.

Shifts of this magnitude make productivity comparisons based

Table 3. Distribution of total construction receipts by type of construction, 1967 and 1977

Type of Construction	1967	1977
Building	68.9	67.3
Single-family homes	19.9	26.4
Apartment buildings	5.5	4.9
Other residential buildings	2.1	1.4
Industrial buildings and warehouses	15.4	12.7
Office and bank buildings	5.8	6.0
Stores, restaurants, public garages, and automobile service stations	4.3	4.4
Religious buildings	2.0	1.0
Educational buildings	8.7	4.0
Hospital and institutional buildings	3.9	4.4
Other nonresidential buildings	1.3	2.0
Nonbuilding	25.9	27.8
Not specified	5.2	4.9

Source: 1967 and 1977 Censuses of Construction Industries on aggregate data highly misleading. As noted above, the technology for home building is much less skilled-labor intensive than the technologies for larger, more complex commercial, industrial, and institutional structures. Such a shift in the mix of output results in a decline in aggregate productivity because sectors with relatively low productivity automatically receive greater weight at the expense of those with relatively high productivity, a classic case of what Jorgensen and Griliches (1967) call an error of aggregation. This bias cannot be eliminated from the raw data because sector-specific indexes are not available to calculate a Divisia index for construction.

To estimate the effect of these changes in output mix on productivity, I examined the changes in the shares of the three contruction mix variables used in the regression model: (1) single-family homes, (2) industrial and office buildings, and (3) educational and hospital buildings. They account for 1.6, 0.7 and 2.2 percent declines in productivity, respectively, representing an overall decline of 4.5 percent. This result is consistent with the findings of Schriver and Bowlby for building construction between 1972 and 1982.

g. Total. The results of the preceding analysis are summarized in Table 4. The model predicts an 8.8 percent decline in productivity, which accounts for 41 percent of the actual decline. The shift in the mix of output away from commercial and institutional buildings and toward single-family houses was the biggest contributor, accounting for 21 percent of the

Table 4. Sources of productivity change in construction, 1968-1978

1. Reported productivity change	-21.4%
2. Estimated sources of productivity change	
a. Capital-labor ratio	-0.9
b. Economies of scale	-1.6
c. Labor quality	-0.7
i. Age, sex distribution	(-3.1)
ii. Years of schooling	(2.4)
d. Percent union	-1.2
e. Regional shifts	0.1
f. Mix of output	-4.5
3. Predicted productivity change	-8.8

Sources: Line 1: unpublished BLS data on output per hour.

Line 2, 3: text.

productivity decline. The declines in the average size of establishments, percent union, and the capital-labor ratio were the three next most important factors, accounting for 7, 6 and 4 percent of the fall in productivity. Labor quality declined somewhat, as an increased proportion of young and female workers was partially offset by an increase in median years of schooling. This factor accounted for 3 percent of the productivity decline. Changes in the regional distribution of construction activity had no effect on productivity.

Although the results of this analysis may not be spectacular in terms of their ability to account fully for the decline in productivity, they go considerably further than previous studies. For instance, Stokes was able to account for only a modest decline in the growth rate of productivity between 1950-1968 and 1968-1978. His residual (unexplained changes in the growth rate) included all of the productivity decline. Nonetheless, it is difficult to reconcile the model's predictions of relatively modest productivity decline with the data. Whether the fault lies with the model or the data remains to be seen.

IV. Has Nominal Output Been Overdeflated?

The deflator used to convert nominal to real output is still heavily based on wage and materials cost indexes. Since the rate of change of wages is positively related to both the general rate of inflation and the rate of productivity growth in construction, such indexes overstate the rate of change in prices of construction projects. As a result, real output will be underestimated.

In spite of this bias, the official measure of real output grew at a 3.8 percent annual rate between 1950 and 1968. Thus it is difficult to attribute the negligible 0.3 percent annual growth in output between 1968 and 1978 to this bias unless the bias worsened during that period. On the surface, this seems to be unlikely, especially when one takes into account the changes in the construction deflator initiated in 1974. True price indexes are available for only two types of construction: single-family homes and highways. Before the revisions, cost indexes were used for all other types of construction. The revised indexes for nonresidential buildings, railroad and military construction are weighted averages of these two price indexes and various cost indexes. In theory, this should have made the bias between 1968 and 1978 smaller.

The impact of these revisions can be gauged by examining the average annual rates of change of each component of the Department of Commerce composite deflator for construction in Table 5. The only price indexes used in the deflator are the Bureau of the Census index for new one-family homes (excluding lot value) and the Federal Highway Administration's (FHiA) indexes for structures and composite highway construction. Between 1950 and 1968 the residential price index grew less rapidly (by about two percentage points) than any other component of the deflator and the FHiA index grew less rapidly than all but one of the cost indexes, as one would expect. In the more recent period, a different pattern emerged. The residential price index still

Table 5. Average annual rates of change in price and cost indexes used in the Department of Commerce Composite Cost Index, 1950-1968 and 1968-1978

Index	1950-1968	1968-1978
NIPA deflator for construction industry	2.7	9.1
Department of Commerce Composite	2.0	8.6
Bureau of the Census new one-family houses excluding lot value	1.7*	8.6
Federal Highway Administration: structures	2.9	9.2
Federal Highway Administration: composite	2.5	9.6
American Appraisal Company	3.8	8.3
Engineering News-Record: buildings	3.7	8.8
Engineering News-Record: construction	4.6	9.2
Environmental Protection Agency: sewers	n.a.	9.5
Environmental Protection Agency: plant	n.a.	9.4
Bureau of Reclamation	2.5	8.2
Turner Construction Company	3.1	7.6
Handy-Whitman public utility: buildings	3.5	9.0
Handy-Whitman public utility: electric	3.3	8.9
Bell System light and Power: buildings	3.2	8.9
Bell System: outside plant	2.6	7.2
Federal Energy Regulatory Commission: pipeline	2.1	8.2

*This index is only available since 1963. The deflator for new residential construction was used for 1950-1962, as reported in Survey of Current Business, August 1974, p. 20.

Sources: 1950-1968, Construction Review, July 1977.

1968-1978, Construction Reports--Value of New Construction Put in Place, May 1983.

rose at a slower rate than most of the cost indexes, but not all of them. Also, the gap between this index and the cost indexes narrowed to less than one percentage point. Despite upward bias, no cost index rose more rapidly than the FHiA composite index. This presents a puzzle--why did the cost indexes and the price indexes grow at roughly the same rate between 1968 and 1978 in contrast to the pattern during 1950 to 1968? Are there any answers other than stagnant or declining productivity?

Two developments in the 1970s provide a partial answer. First, to the extent that extremely high inflation rates caused the prices to single-family homes to grow more rapidly than the prices of nonresidential buildings, the use of the housing price index in the deflator for nonresidential buildings has resulted in additional upward bias. To understant why, consider the effect of inflation on housing prices under the tax codes. The size of tax deductions for interest payments increases by the same proportion as the interest rate, which, in turn, rises much more proportionally than the overall price level. For instance, suppose 5 percent inflation increases interest rates from 4 to 9 percent. Tax deductions would more than double despite a relatively much smaller increase in prices. This lowers the user cost of housing and increases demand for owner-occupied housing. Even though interest costs are deductible for other types of private construction, demand will grow less rapidly because both depreciation and profits from sale of a project are based on historical cost. Other things equal, prices for nonresidential construction should have grown less rapidly than residential. While housing prices increased at an annual rate of 8.6 percent between 1968 and 1978, the Turner Construction Company cost index increased at a rate of 7.6 percent. Thus, the use of the housing price index for nonresidential buildings resulted in a higher estimate of the rate of price change than would have been obtained with the upwardly biased cost indexes previously used in the price deflator.

The other development was changes in the mix of highway construction. In addition to a shift from rural to urban highway construction, the projects completed in rural areas changed considerably between 1968 and 1978 as a result of the near completion of the interstate highway system. This system accounts for most of the capital outlays for new highway construction in both periods. The rural segments were largely complete by 1968 except for some short segments in areas in which geographical factors made costs per mile especially high. This is reflected in a rapid rate of increase in excavation costs between 1968 and 1978. Excavation costs increased at an annual rate of 11.4 percent, 1.4 percentage points more than the rate of increase in the rural composite index. Since the Federal Highway Administration (FHiA) index makes no adjustments for changes in highway characteristics over time, this index overstates the true rate of price change between 1968 and 1978. This bias can be at least partially eliminated by using an index based on urban construction only. In addition to controlling for urban-rural shifts, it also avoids the bias resulting from the changing character of rural construction. Urban highway construction may very well have changed in a similar fashion; if this is so, some upward bias remains. Urban highway construction costs increased at an annual rate of 8.4 percent over this period, 1.2 percentage points slower than the FHiA composite index.

There is no easy solution to the bias resulting from the inappropriate use of the residential deflator for nonresidential building construction. One alternative is to give greater weight to the cost indexes, but the fundamental problem of upward bias in both periods remains. Instead, I propose a deflator equal to the difference between the rate of change of value put in place and the rate of change of square footage put in place for nonresidential building construction as reported by Dodge Construction Potentials. This deflator increased at an average annual rate of 6.9 percent between 1968 and 1978. This rate is only moderately slower than the growth of other indexes--1.7 percentage points slower than the index for homes and 1.9 percentage points slower than the median of all the cost indexes used in the composite deflator. These differences are consistent with the direction of the biases described above. Although the magnitude of these biases is impossible to gauge, it seems to me more plausible for them to be in this range as opposed to, say, less than one or more than four or five percentage points.

An obvious potential problem with this deflator is the assumption that square footage is a reliable measure over time of nonresidential output. One problem is that the mix of nonresidential construction changes over time. This calls for the use of separate deflators for each type of nonresidential construction, weighted by their share of output. Within each type of construction, the square footage measure ignores changes in building and locational characteristics. I cannot estimate directly the magnitude of this type of bias, but I can do so indirectly by estimating cross-section hedonic price equations for commercial office buildings, elementary and secondary schools, hospitals and nursing homes, and federal buildings. In a cross section, the price (contract amount) of the building is the best measure of output. It is not a perfect measure because of possible locational differences in prices, but this influence can be largely removed by using dummy variables for regional and urban location. If square footage is a good approximation to output, then this variable will explain almost all of the cross-section variation in prices, and building characteristics will account for very little of it. On the other hand, if building characteristics play a dominant role in determining output, square footage will leave unexplained much of the cross sectional variation in prices. Also, if square footage is a valid measure of output, the coefficient of square footage in a log-log specification should equal one.

The results in Table 6 show that 89-to-95 percent of the price variation in each sample can be explained in terms of square footage. In the office building sample, building

Table 6. Coefficients and standard errors of hedonic price equations for commercial office building, elementary and secondary school, hospital and nursing home, and federal building construction

Sample	Commercial office buildings		Elementary and secondary schools		Hospitals and nursing homes		Federal buildings	
Intercept	3.221	3.876	2.490	3.200	4.637	5.959	5.210	5.806
	(.264)	(.556)	(.510)	(.660)	(.596)	(.754)	(.552)	(.635)
ln (square feet)	.995	.868	1.058	.961	.941	.696	.895	.886
	(.024)	(.056)	(.049)	(.049)	(.051)	(.073)	(.046)	(.055)
Northeast		.351		.411		.442		-.032
		(.132)		(.064)		(.112)		(.137)
North Central		.109		.102		.083		-.118
		(.102)		(.063)		(.091)		(.096)
West		-.050		.243		.264		.071
		(.142)		(.076)		(.114)		(.180)
SMSA		.068		.139		.062		-.119
		(.110)		(.056)		(.102)		(.108)
Building characteristics included	No	Yes	No	Yes	No	Yes	No	Yes
σ	.357	.310	.287	.182	.322	.188	.286	.168
R^2	.954	.973	.891	.963	.889	.978	.944	.990
N	83	83	68	68	44	44	24	24

Note: The dependent variable is ln (contract amount). Its mean (S.D.) is 13.883 (1.649) for commercial office buildings; 14.310 (0.862) for schools; 15.543 (.985) for hospitals and 15.816 (1.185) for federal buildings. Building characteristics used in the office building equation include percent of interior completed and dummy variables indicating number of stories above and below ground, type of heat, interior wall, roof base, and presence of elevators or escalators. Characteristics used in the school equation include ratio of classroom to total square footage and dummy variables indicating elementary schools, number of stories, use of prefabricated components, type of interior wall, and presence of a swimming pool. Characteristics in the hospital equation include number of beds (in logs), number of stories, and dummy variables indicating type of heat, type of foundation, use of pile footings in the foundation, and presence of a cafeteria. Characteristics in the federal building equation include number of stories and dummy variables indicating type of heat and the use of pre-cast concrete walls, plumbing pipe "trees" and electrical conduit "trees," and movable or demountable wall partitions. Other building characteristics were not included because either (1) the coefficients had a sign different than that implied by engineering data in 1977 Dodge Construction systems costs or (2) the coefficients were smaller than their standard errors.

characteristics and location variables explain only an additional 2 percent of the price variation. These variables do slightly better in the other equations, accounting for an additional 5-to-9 percent of the price variation. Even though square footage is a deficient measure of output, the magnitude of the deficiency seems to be very small.

If nonresidential buildings have become more amenity-intensive (as is the case in residential construction), this deficiency will be in the direction of understating the rate of growth in output, making my proposed deflator overstate the rate of growth in prices.

The hypothesis of a unitary coefficient for square footage cannot be rejected in the models for which building characteristics are excluded. It varies greatly from one when those characteristics are included in only the hospital samples.

Based on the above discussion, how much has nominal output been overdeflated? I have proposed to use the FHiA urban composite index for highway construction and an index derived from aggregate value put in place and square footage data for building construction other than single-family homes. Assuming the Census index for single-family homes accurately measures price changes in that sector, only one type of construction needs further attention: nonbuilding construction other than highways. This largely consists of public utility, water, sewer, and conservation projects. Lacking any price data for any of these types of construction, I will use a deflator equal to the simple average of the FHiA urban composite deflator and the deflator based on square footage and value put in place in nonresidential buildings.

To obtain a price index for the industry, I took the share-weighted average of these four sectoral indexes, basing the shares on value put in place. Using weights equal to the simple average of the 1968 and 1978 shares, the index for the industry increases at an annual rate of 7.7 percent between 1968 and 1978. This is 1.4 percentage points less than the deflator used in the national income accounts for the construction industry and 0.9 percentage points less than the Department of Commerce Composite Index. The new index implies productivity fell by 10.5 percentage points between 1968 and 1978, 10.9 percentage points less than the decline in productivity as measured by BLS. Thus, overdeflation of nominal output could account for 51 percent of the measured productivity decline.

This new price index is admittedly ad hoc with respect to nonbuilding construction other than highways; there is no way to determine whether this component of the index is biased in either direction. However, the cost indexes currently used in the NIPA deflator overstate the rate of price increase, which suggests that an index that grows at a 0.9 to 1.4 percentage point slower rate should not be rejected out of hand. As for its other components, this new index probably overstates the rate of price increase. There is no adjustment for likely increases in amenities or improved design in the proposed index for nonresidential buildings. As noted earlier, the urban highway construction index does not control for changes in highway characteristics within urban areas over time. The new index is admittedly no substitute for a complete and careful revision of the NIPA deflator based on micro data on a variety of different types of projects over the entire period, but it seems difficult to claim that it is not preferable to the official deflators for the purposes of this analysis.

V. Has Nominal Output Been Underestimated?

Census estimates of value put in place are based on a monthly sample of projects. These projects are identified by four sources: F.W. Dodge reports of new building projects in 37 eastern states and the District of Columbia, the Census monthly Building Permits survey in the 13 western states for projects with permit values of $500,000 or more, a separate sample of places issuing building permits in the western states for projects with permit values of less than $500,000, and reports from a variety of sources such as building materials dealers and utilities officials in areas of the western states where building permits are not required. A Census study in the late 1960s compared Dodge reports in the eastern states to a sample of projects obtained from building permit data and found that a significant percentage of construction projects were not being reported by Dodge. Accordingly, the results of the sample survey in the eastern states have been increased by 15 percent for some time. The results for the western states are increased by 5 percent to allow for undercoverage of construction done in areas in which permits are not required.

Two recent studies suggest that the volume of nonresidential building construction is being drastically underestimated. Sampling rates from all four sources of project data are based on project size. All projects costing $5 million or more are to be included in the sample. Business Rountable (1982) reported a number of instances in which companies were not receiving any requests from the Census Bureau to provide data on projects in this size category. Even when they are asked to participate in the survey, many companies refuse because of the costs involved (reporting is not compulsory). The Business Roundtable report concludes, "The project identification and sampling procedures are not working."

The other warning signal comes from a paper by Alan Blum (1980) of the Census Bureau comparing measured output for 1977 in the Value of New Construction Put in Place (VIP) series and the CCI. After making a number of adjustments to make the two data sets comparable, Blum found the CCI was reporting 75 percent more industrial construction and 29 percent more hospital and institutional construction than the VIP.

A comparison of the growth of nonresidential building construction between 1967 and 1977 from these two sources provides further evidence of an undercount. Since CCI does not provide public-private breakdowns, both sectors are considered together. The VIP series increases from $26.9 to $40.6 billion over this period, while the CCI series increases from $38.2 to $72.8 billion. Since the CCI series includes work subcontracted to others (28 percent of total receipts), the 1967 figures are quite comparable. The key finding is the dramatic difference in the growth of the two series. The CCI measure increased by 91 percent, whereas the VIP measure increased by only 51 percent.

This suggests the undercount in nonresidential building is a relatively recent phenomenon and thus may have contributed to the decline in measured productivity. However, this argument ignores the other side of the NIPA ledger: the income source accounts. Even if structures are being underestimated in the output source accounts, the income source side must be taken into account to be fully consistent. Accordingly, it would be inappropriate until further evidence is available to claim that an undercount of output has been a source of the observed productivity decline.

VI. Conclusion

This study's two major findings are summarized in Table 7. First, labor productivity in the construction industry should have declined by 8.8 percent between 1968 and 1978. The biggest factor in this decline is the reduction in skilled labor intensity resulting from the shift in the mix of output from large scale commercial, industrial, and institutional projects to single-family houses. Other important factors include declines in the average number of employees per establishment, capital-labor ratio, percent union, and the average age of

Table 7. Summary of analysis of productivity change

Predicted productivity change from production function estimates	-8.8
Adjustment for bias in price deflator	-10.9
Sum of predicted productivity change and adjustments for bias in price deflator	-19.7
Reported productivity change	-21.4
Percentage of reported productivity change explained	92.0

workers. Second, growth in real output in construction is considerably greater than indicated by the national income accounts. The difference between the official deflator and the alternative deflator proposed in Section IV accounts for about half the observed productivity decline. After making adjustments for all these factors, the predicted decline in measured productivity is 19.7 percent. This accounts for 92 percent of the reported productivity decline.

Although this approach quite successfully explain productivity changes between 1968 and 1978, it does not do as well over the 1950-1968 period. As outlined in detail in the appendix, the model predicts a 34.4 percent increase in productivity, whereas BLS reports a 48.9 percent increase. The actual productivity increase was no doubt higher because of upward bias in the price deflator. Based upon the same adjustment outlined in Section IV, my estimate is that productivity actually grew by 52.4 percent. Although the sources of almost two-thirds of this productivity growth are identified by the model, a substantial residual remains. This could result from omission of variables from the analysis. For instance, there are no data, to my knowledge, on research and development expenditures for the construction industry. If there were a great deal of R & D spending in the 1950s and 1960s but relatively little in the 1970s, then the productivity changes for both the 1950-1968 and 1968-1978 periods might be explained fully by the model. Trends in the ratio of new construction to alteration and repair construction may have varied between these two periods as well.[8] Changes in the production function and errors in measuring changes in the levels of the independent variables may also account for the relatively poorer performance of the model in this earlier period. Whatever the reason, this analysis suggests that the real productivity puzzle in construction is not the negative residual between 1968 and 1978, but the positive residual between 1950 and 1968.

Notes

[1]Even before 1968, many observers felt construction lagged behind the rest of the economy in terms of productivity growth. Data on productivity change by industry reported in Baily (1981) do not bear this out. Between 1948 and 1968 labor productivity grew more rapidly in construction than in manufacturing, finance, retail trade, and services. However, while productivity continued to grow in most other sectors of the economy between 1968 and 1978, it was falling in construction. Only the mining industry had worse productivity performance over this period.

[2]These variables were chosen because the shares of each of these categories changed considerably between 1968 and 1978. Variables representing other types of construction were also examined but are not included in the specification because their coefficients were estimated with very little precision.

[3]These figures are reported in U.S. Department of Labor (1972, 1981a, 1981b, 1983).

[4]These unpublished series were kindly provided to me by Ken Rogers of BIE and Elliot Grossman, a contractor of the American Productivity Center.

[5]Stokes uses a BIE series that ends in 1974.

[6]The BIE uses a Beta decay function with β=0.9 for structures and 0.75 for equipment. The APC measure is based on initial estimates by John Kendrick, who uses a declining balance formula.

[7]This analysis was also done with regional shares of value added in the 1967 and 1977 CCI, which produced nearly identical results.

[8]This was suggested by an anonymous referee.

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<u>Appendix</u>

The same methods used to determine the sources of the productivity decline in construction between 1968 and 1978 can be used to analyze the sources of productivity growth between 1950 and 1968. As no censuses of the construction industry were taken in the 1950s, the effects of changes in employees per establishment and the mix of output had to be examined with different data sources. Otherwise, the results below were obtained in exactly the same fashion as those in the text for the 1968-1978 period.

a. <u>Capital-labor ratio</u>. The American Productivity Center's fixed capital measure grew at an annual rate of 6.8 percent between 1950 and 1968, while the BLS measure of labor hours grew at a 1.5 percent rate. Based on the change in the logarithm of the capital-labor ratio over this period, this should have resulted in a 22.3 percent productivity increase.

b. <u>Economies of scale</u>. The growth in employees per establishment between 1953 and 1968 was calculated from <u>County Business Patterns</u>. (Data for 1950 were not available.) The average establishment had 10.1 employees in 1968, an increase of 1.1 employees over 1953. Extrapolating the logarithmic change in this ratio over the 1950-1968 period, increased establishment size resulted in a 2.4 percent productivity increase.

c. <u>Labor quality</u>. Changes in the age and sex distribution of workers, as reported by Stokes, caused the labor quality index to fall by 0.8 percent, resulting in an identical percentage decline in productivity. Mean years of schooling increased from 9.5 to 11.3 between 1950 and 1968, resulting in a 4.4 percent increase in productivity. The net result of these changes in the quality of work force is a 3.8 percent increase in productivity.

d. <u>Percent union</u>. Adjusted union membership grew by 28.6 percent between 1950 and 1968, whereas BLS employment grew by 35.0 percent. This implies percent union in 1968 was 95.2 percent of percent union in 1950 and sets percent union in 1950 at 40.9. A decline in percent union of 1.9 percentage points results in a 0.3 percent decline in productivity after adjusting for the downward bias of the union coefficient in Table 2.

e. <u>Regional shifts</u>. Between 1950 and 1968 the shares of employment in the Northeast, North Central and Western regions declined by 3.0, 1.7, and 1.5 percentage points, respectively. This resulted in a 0.3 percent decline in productivity.

f. <u>Mix of output</u>. The impact of changes in the mix of construction activity was determined by comparing the shares of different types of construction in <u>Value of New Construction Put in Place</u> for 1951 and 1968. I chose not to use 1950 as the initial year because residential construction represented 54 percent of total construction in that year, a figure which was significantly out of line with those for all subsequent years. The following shares were constructed to make these data as comparable as possible to the Census of Construction Industries categories in Tables 2 and 3:

	1951 share	1968 share
New housing units and farm dwellings	.391	.275
Industrial and commercial buildings	.102	.158
Private and public educational, hospital and institutional	.079	.108

Extrapolating the predicted effects of these changes an additional year, the model predicts a 6.7 percent increase in productivity.

g. Bias in the deflator. Weighting by the simple average of 1951 and 1968 shares, my proposed price deflator rises at an annual rate of 2.3 percent, 0.4 percentage points below the NIPA deflator. This implies productivity increased by 52.4 percent between 1950 and 1968 in contrast to the 48.9 percent increase reported by BLS.

h. Total. The combined effect of these factors is a predicted productivity change of 34.4 percent based on changes in the capital-labor ratio, employees per establishment, labor quality, percent union, and the regional and industrial mix of output. After adjusting for upward bias in the deflator, productivity actually increased by 52.4 percent. The model thus accounts for 65.6 percent of the actual change in productivity.