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8 The Measurement of Construction Prices: Retrospect and Prospect

Paul E. Pieper

The deflation of construction expenditures is both one of the most difficult and one of the most important areas of national income accounting. Accurate deflation is essential for a number of issues, including measuring construction productivity and measuring the real capital stock. However, developing accurate structures deflators is very difficult due to the heterogeneity of most structures. This difficulty has in the past been compounded by a lack of resources devoted to construction deflation.

As the title suggests, this paper takes both a retrospective view of past construction deflation methods and a look forward at possible ways of improving the existing deflators. Section 8.1 reviews the development of the Bureau of Economic Analysis' (BEA) construction deflators. The section discusses both the improvements that have been made over the past 40 years and the weaknesses that still remain. Section 8.2 reviews the academic literature on construction deflation. This section evaluates and updates the work of a number of earlier authors and examines whether the BEA has overdeflated construction output. The final section discusses the strengths and weaknesses of different deflation methods.

8.1 The Development of the Department of Commerce Construction Deflators

The problem of construction deflation stems from the extreme heterogeneity of structures. Because most structures are unique, most construction deflators do not price a complete prototype structure. Instead, inputs or intermedi-

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ate units of output are deflated. The term "cost index" will be used here to refer to a weighted average of input prices.[1] Most cost indexes are simple averages of materials prices and wage rates although a few attempt to measure overhead costs and profit. The main problem with cost indexes is that they assume the same relationship between inputs and output over time, or, in other words, they assume constant productivity. Cost indexes will thus be biased upward if productivity is increasing. A few cost indexes attempt to adjust labor costs for productivity, but the adjustment is usually arbitrary or subjective.[2]

Other construction deflators attempt to price intermediate units of output termed components. Components may refer to a specified quantity of materials in place or some physical attribute such as square feet. While each structure may be unique, it is assumed that they are composed of a number of homogeneous components. The term "component-price index" is used in the construction literature to refer to an average of the price of one or more components. This paper will use the more succinct term "price index" to refer to indexes that price some form of construction output rather than construction inputs.

The Department of Commerce first published a deflator for new construction expenditures in September 1946.[3] The deflator was an expenditure-weighted average of 12 indexes, all but two of which were cost indexes instead of price indexes. The two exceptions were the Bureau of Public Roads' highway price index and the Interstate Commerce Commission's (ICC) railroad price index. Both indexes measured the price of specified quantities of materials in place, such as cubic yards of concrete or pounds of steel. The prices were based on contractors' bids for these items in newly awarded contracts and reflected not just materials costs but all construction costs. Since the two indexes together had only about a 10% weight, an implicit deflator for new construction (hereafter termed the composite) was still essentially an average of wage rates and materials prices.[4] From the beginning, the Commerce Department recognized the limitations of such an index. It admitted that its constant dollar estimates of new construction would "provide only crude indicators of physical change" (U.S. Department of Commerce, Office of Domestic Commerce 1947, 25).

Though well aware of its defects, the Department of Commerce did not make a single change in the composite for the first 17 years of its existence. Construction deflation did not receive widespread attention until the NBER's Price Statistics Review Committee (also known as the Stigler committee after its chairman, George Stigler) issued its report in 1961. The report was highly critical of the composite, terming it "defective in almost every possible way" (NBER 1961, 87). Its primary criticism was that the composite relied almost entirely on cost indexes that assumed no change in construction productivity. The Stigler committee was also very critical of the methodology of the cost indexes. For example, it stated that the indexes were unrepresentative of the expenditures they were used to deflate, both in terms of geographic coverage and in terms of the inputs priced. Other problems included a failure to use transaction prices and inaccurate and outdated weights. No fewer than eight of the 10 cost indexes used weights based on the 1910–14 period. Finally, most of the indexes were compiled by private firms that were either unwilling or unable to provide detailed descriptions of their methodology.

The Stigler committee recommended "a radical expansion and reorientation" of research in construction deflation (NBER 1961, 29). It suggested in particular developing a residential deflator based on the price per square foot of various categories of new homes. Following this suggestion, the Census Bureau began collecting data on single-family homes in 1963. Its subsequent experiments with a hedonic price index lead to the creation of the census single-family homes price index (hereafter termed census index). The census index replaced the Boeckh cost index as the BEA's deflator for residential construction in 1968, for the period from 1963 onward.

The census regressed the sales price of new single-family homes against eight housing characteristics: square feet of floor space, number of bathrooms and stories, metropolitan and regional location, and presence of a garage, basement and central air conditioning.[5] A Laspeyres price index was then formed by multiplying the regression coefficients by the base-year averages of the characteristics. The BEA initially adjusted the index for land costs using Federal Housing Authority (FHA) site-to-value data. Land costs were estimated by the survey respondent beginning in 1969.

The BEA made two other deflation changes during the sixties. The ICC railroad index ceased publication in 1967. Until the introduction of the census index a year later, this left the Bureau of Public Roads index as the sole price index in the composite. The other change was the introduction of the AT&T cost index for telephone construction in 1963.

The Stigler report set in motion a long review of the existing construction deflators, which finally culminated in a major revision of the deflators in 1974. Six cost indexes, all but one privately compiled, were dropped from the composite. Three indexes were added, including two that were, in part, price indexes. The Federal Energy Regulatory Commission (FERC) pipeline index and the Bureau of Reclamation index, used in deflating conservation and development expenditures, were hybrid indexes, part price index and part cost index. For example, the Bureau of Reclamation index is an average of a number of individual indexes, some of which measure the price of excavation and structural concrete in place, but others that are simple averages of wage rates and materials prices.

The most problematic area for deflation was probably nonresidential buildings. The revised construction deflators included four indexes that were at least in part price indexes: the Bureau of Public Roads, Bureau of Reclamation, FERC, and census indexes. The first three indexes were based on the nonbuilding sector, while the census index represented the residential sector.

Lacking an available price measure for nonresidential buildings, the BEA took an unweighted average of the census, Turner construction company, and Bureau of Public Roads structures indexes. The Turner index measures the cost of office construction, while the Bureau of Public Roads structures index is a subindex of the Bureau of Public Roads index measuring the price of highway structures such as bridges and overpasses. Since the Turner index was the only cost index of the three, this procedure greatly increased the percentage of construction deflated by price indexes. The obvious drawback to this method was that the Turner index was also the only one of the three indexes that was actually based on the nonresidential building sector.

The 1974 revisions form the basis for much of the present BEA deflation methodology. However, the BEA has made a number of modifications over the past 14 years, including the net addition of two indexes. A new deflator for military construction was first published in 1983 (Sachs and Ziemer 1983). The military deflator is based on a variety of physical measures of output, most commonly square feet in the case of buildings and materials in place in the case of nonbuilding construction. The second addition was the consumer price index for maintenance and repair expenditures, which was given a 50% weight in the deflator for residential additions and alterations. On the other hand, the AT&T cost index for telephone construction was discontinued in 1983 after the breakup of AT&T. It was replaced by the Engineering News-Record index, a very simple cost index.

Nonresidential buildings continue to be a problematic area for deflation. Because of the volatility of the highway structures index during the seventies and early eighties, the BEA removed it from the private nonresidential building deflator during the 1985 benchmark revisions. Presently, private nonresidential buildings are deflated by an average of the census and Turner indexes, while public buildings use various combinations of the census, Turner, and highway structures indexes. The BEA also changed the form of the census index from a Laspeyres index to a Paasche index.

Table 8.1 summarizes a few main characteristics of the BEA deflation methodology. The table compares three different composite construction deflators, each of which represents a major phase in the development of the BEA's methodology. BEA I is based on the deflation methodology at the time of the Stigler committee's report in 1961. BEA II represents the methodology of the 1974 revisions, while BEA III refers to the present (1988) method of deflation. Since 1961 there has been a large increase in the use of price indexes. There are presently six total or partial price indexes in use compared to only two in 1961. The present price indexes also have a disproportionate weight, deflating about two-thirds of new construction versus only 11% under BEA I. This percentage is down slightly from 1974, largely due to the increased weight of the Turner cost index in the nonresidential building deflator. Since most of the price indexes are also government compiled, there has been

Table 8.1 **Selected Characteristics of the BEA Composite Construction Deflators, 1982 Expenditure Weights**

	BEA I	BEA II	BEA III
1. Number of component indexes	12	9	11
2. Number of price indexes[a]	2	4	6
3. Number of government compiled indexes	3	5	7
4. Percentage of construction deflated by prices indexes:			
Residential	.0	100.0	100.0
Nonresidential buildings	.0	66.7	49.5
Nonresidential nonbuilding	38.2	44.7	42.9
Total construction	10.9	72.7	66.4
5. Percentage of construction deflated by government-compiled indexes:			
Residential	1.9	100.0	100.0
Nonresidential buildings	.0	66.7	49.5
Nonresidential nonbuilding	43.5	66.4	63.2
Total construction	13.2	78.9	72.2
6. Percentage of construction deflated by proxy indexes:			
Residential	53.0	55.4	32.6
Nonresidential buildings	68.5	89.9	85.3
Nonresidential nonbuilding	31.8	30.3	33.8
Total construction	52.3	59.7	51.0
7. Percentage of construction deflated by both price and nonproxy indexes:			
Residential	.0	45.6	67.4
Nonresidential buildings	.0	.0	.0
Nonresidential nonbuilding	37.3	25.8	29.1
Total construction	10.7	24.3	33.4

Source: See appendix.
Note: The headings BEA I, BEA II and BEA III refer to the BEA's deflation methodology in the years 1961, 1974, and 1988, respectively.
[a]Includes hybrid indexes

a similar rise in the percentage of construction deflated by government compiled indexes.

On the other hand, the BEA has made little progress in reducing the use of "proxy" indexes. The term proxy index is used here to refer to an index based on a different sector of construction than the one it is used to deflate. An example is the use of the census single-family homes index to deflate nonresidential buildings. In order to quantify this, construction was divided into 19 sectors corresponding roughly to the breakdown in the national income and product accounts. About half of all new construction is deflated by indexes based on other sectors, or nearly the same percentage as in 1961. The main sectors lacking their own deflators are multiunit residential construction and most types of nonresidential buildings.

A more stringent criteria for evaluating the construction deflators is the percentage of construction deflated by both a price index and a nonproxy index. Only about one-third of new construction meets both criteria, consisting mostly of single family homes and highways. Seen in this light, progress in construction deflation has been quite limited over the past 40 years. One problem is that some of the BEA's present price indexes represent small construction sectors such as petroleum pipelines, military and conservation and development. Little or nothing is known of price movements in the important nonresidential building, public utility, and multiunit residential sectors.

Table 8.2 lists the individual indexes used to deflate construction. The main feature is the very large weight of the census index in the BEA II and BEA III deflators. Altogether about one-half of new construction is presently deflated by the census index, including multiunit residential and half of nonresidential

Table 8.2 **1982 Weights of the BEA Construction Deflators**

	BEA I	BEA II	BEA III
Cost indexes	89.1	23.9	30.7
1. U.S. Department of Agriculture	2.2	.0	.0
2. American Appraisal	17.4	.0	.0
3. Associated General Contractors	4.0	.0	.0
4. AT&T	.0	2.9	.0
5. Boeckh	36.4	.0	.0
6. *Engineering News-Record*	4.0	.0	2.9
7. Environmental Protection Agency	.0	2.8	2.8
8. Fuller	9.6	.0	.0
9. Handy-Whitman	7.5	6.0	6.9
Buildings	.8	.6	.6
Electric utility	5.5	5.4	6.3
Gas utility	1.2	.0	.0
10. Turner Construction Co.	7.9	12.2	18.0
Combined cost and price indexes	.0	5.9	5.3
1. Bureau of Reclamation	.0	3.9	3.3
2. Federal Energy Regulatory Commission Pipeline	.0	2.0	2.0
Price indexes	10.9	70.2	64.0
1. BEA Military	.0	.0	1.0
2. Census Single-Family Homes	.0	49.3	46.4
3. CPI Maintenance and Repair	.0	.0	8.1
4. Federal Highway Administration	6.8	20.9	8.5
Composite	.0	11.9	1.0
Structures	6.8	8.9	7.5
5. ICC Railroad	4.1	.0	.0

Source: See appendix.

Table 8.3 Annual Rates of Change of BEA Composite Deflators, 1963–1982, 1982 Expenditure Weights

	1963–82	1963–72	1972–82
1. Total construction			
BEA I	7.2	6.0	8.3
BEA II	7.0	4.9	9.0
BEA III	7.0	4.9	9.0
2. Residential construction			
BEA I	7.2	6.2	8.2
BEA II	6.9	4.1	9.5
BEA III	7.0	4.4	9.4
3. Nonresidential buildings			
BEA I	7.3	6.2	8.2
BEA II	7.1	5.6	8.5
BEA III	7.1	5.3	8.7
4. Nonbuilding construction			
BEA I	7.2	5.6	8.6
BEA II	7.0	4.9	8.9
BEA III	7.1	5.1	8.9

Source: See appendix.

buildings. Next to the census, the two most important indexes are the Turner and Federal Highway Administration (formerly Bureau of Public Roads, abbreviated here FHWA), which together have about a 25% weight. These two indexes and the two Handy-Whitman indexes are the only indexes that have been used continuously since the introduction of the composite in 1946.

Table 8.3 calculates rates of change of fixed weight construction deflators using the three methodologies. The 1963–82 period was chosen for comparison because the endpoints are BEA benchmark years and, more important, because it is the only period in which most of the component indexes overlap.[6] Despite using different methods, the three composites show remarkably similar rates of increase in all construction sectors over the 1963–82 period. This similarity is surprising given that BEA I is heavily dependent on cost indexes while BEA II and BEA III are based mostly on price indexes. All other things equal, a cost index will increase faster than a price index if productivity growth is positive. Thus the BEA's use of cost indexes has been heavily criticized in the past for imparting an upward bias to the composite. However the increased use of price indexes in the BEA II and BEA III composites has not appreciably lowered the measured rate of construction inflation.

The similarity of the three deflators over the 1963–82 period masks major differences over the two subperiods. Although BEA I increases faster than the other two deflators in the 1963–72 period, it actually increases 1% per year slower in the 1972–82 period. The BEA I deflator, therefore, shows only a two-percentage-point increase in inflation between the two subperiods compared to the four-percentage-point increase in the BEA II and BEA III deflators. That the BEA III deflator could increase significantly faster than a cost index could be taken as evidence of an upward bias in the BEA deflator in the seventies but it would also be consistent with an actual decrease in construction productivity.

Although most critics of the BEA construction deflators have been concerned with their ability to measure the long-run trend of prices, for some purposes the ability to accurately measure short-run price movements is equally or more important. There are several reasons for believing that cost indexes will understate the change in construction inflation over the business cycle. For one, cost indexes usually do not measure the contractor's profit. Since profits are procyclical, this will understate the extent of cyclical fluctuations in prices. Second, cost indexes by definition fail to fully account for productivity. Gordon (1968) has presented evidence that construction productivity is countercyclical, falling during expansions and rising during slumps. Therefore construction prices will tend to increase faster than costs during expansions and slower during contractions.

In addition, many cost indexes do not use actual transaction costs but use instead union wage scales, list prices of materials, or other types of quoted prices. For example, the American Appraisal cost index for industrial buildings, used in the BEA I composite, made "no allowance for the extreme costs resulting from overtime wages, premiums on materials or sacrifice prices and omissions of overhead costs and profits during depression periods" (U.S. Department of Commerce, Office of Business Economics 1956, 210). These are of course some of the same reasons why construction prices fluctuate. The use of nontransactions prices will therefore give the indexes an artificial stability.

For the reasons outlined above, cost indexes will generally be insensitive to changes in competitive conditions. In order to quantify this, construction inflation ($\dot{P}$) was regressed against lagged inflation and the gap between actual and trend real construction activity (GAP):

$$\dot{P}_t = b_0 + b_1\dot{P}_{t-1} + b_2\,\mathrm{GAP}_t, \tag{1}$$

The trend level of construction activity was determined as the predicted value of a regression of the log of construction employment against a time trend.[7]

Equation (1) can be thought of as a Phillips curve for the construction industry. The main coefficient of interest is, of course b_2, which measures the response of prices to the level of construction activity. This coefficient should be positive and, if the preceding arguments are correct, higher for price indexes than cost indexes. Results of regressions of the three composites are shown in table 8.4. The gap coefficient for the BEA I composite is smaller than the other composites, reflecting the early composite's heavy use of cost indexes. However the difference is statistically significant only between the BEA I and BEA II composites and only at the 10% level. To put the point estimates in perspective, construction employment is about 10% below its trend level in a major recession such as in 1982. This would reduce the inflation rate as measured by the BEA I composite by about 2%, versus 4.9% for the BEA II measure.

Lines 4–8 of table 8.4 compare the behavior of individual indexes. The main feature is the high sensitivity of the FHWA structures index, which is undoubtedly due to the index's use of bid prices.[8] The gap coefficient of the Turner cost index is also statistically significant, which may be partly due to Turner's subjective adjustment of the index for competitive conditions. On the other hand, the gap coefficient of the American Appraisal index is close to zero, reflecting its use of list prices. The census index has a larger gap coefficient than the Boeckh cost index but the difference is not statistically significant. However the census index probably understates the change in prices over the business cycle because it ignores buyer incentives that effectively act as price reductions. Buyer incentives such as below-market financing were both common and of significant size during the 1981–82 recession. The census index increased by 2% during 1982 but the true rate of price change was probably negative.

Table 8.4 **Rates of Construction Inflation and the Output Gap**
$\dot{P}_t = b_0 + b_1 \dot{P}_{t-1} + b_2 \text{GAP}_t, \quad t = 1965\text{–}82$[a]

		Regression Coefficients				Tests of Equality of b_2 Coefficient[b]	
Equation	Index	b_0	b_1	b_2	$\bar{R}^2$	Equations	f-Statistic
Total construction:							
1.	BEA I	3.846	.476	.203	.577	(1),(2)	3.43
		(1.145)	(.150)	(.066)			
2.	BEA II	4.714	.318	.489	.456	(2),(3)	.63
		(1.527)	(.177)	(.140)			
3.	BEA III	3.444	.507	.354	.561	(3),(1)	1.61
		(1.258)	(.154)	(.098)			
Single-family homes							
4.	Boeckh	3.415	.560	.011	.311	(4),(5)	2.39
		(1.532)	(.210)	(.073)			
5.	Census	2.941	.588	.147	.483	—	—
		(1.368)	(.167)	(.077)			
Nonresidential structures							
6.	American appraisal[c]	5.355	.262	.058	.014	(6),(7)	2.96
		(1.834)	(.255)	(.123)			
7.	Turner	4.286	.396	.371	.349	(7),(8)	6.48
		(1.552)	(.190)	(.134)			
8.	FHWA structures	8.654	−.160	1.471	.374	(8),(6)	10.87
		(2.854)	(.195)	(.411)			

[a]Ordinary least squares; standard errors are shown in parentheses.
[b]Tests the equality of coefficient b_2 between the equations listed. Critical values are $F_{.10} = 2.63$, $F_{.05} = 4.17$, and $F_{.01} = 7.56$.
[c]Regression for the 1965–81 period. $\dot{P}$ = percentage change in the construction price index. The composite indexes are calculated using fixed 1982 expenditure weights. GAP = difference between actual and trend construction activity as a percentage of trend.

In conclusion, there are some significant differences in the short-run movements of cost and price indexes. Given that two-thirds of new construction is still deflated by either cost or proxy indexes, the BEA deflators still probably understate the true extent of cyclical price fluctuations.

8.2 Alternative Construction Deflators

The Stigler committee's report in 1961 coincided with an increased interest in construction deflation among academic economists. Interest in construction deflation was prompted in large part by research in the process of economic growth and by growth accounting models in particular. Pinpointing the sources of economic growth required accurate measures of real capital, which in turn lead researchers such as Gordon (1961) and Kendrick (1961) to question the existing construction deflators. By the early sixties, the deficiencies of the commerce deflators were well known, but there were as yet no alternative deflators available.

Responding to the demands of researchers, the BEA in 1966 published an alternative deflator for private nonresidential construction, which it termed "constant cost 2" (Grose, Rottenberg, and Wasson 1966). The constant-cost-2 deflator was a weighted average of five indexes, with by far the largest weight given to the Bureau of Reclamation index. Component indexes of the Bureau of Reclamation index were used to deflate several types of construction, including buildings and electric and gas utilities. The constant-cost-2 deflator also included the AT&T cost index, the Turner cost index and the FHWA index, and a small weight for the ICC railroad index.

The constant-cost-2 deflator was probably only a marginal improvement over the BEA I composite. It relied heavily on the Bureau of Reclamation index, which was only partly a price index and often distantly related to the expenditures it deflated. About two-thirds of the Bureau of Reclamation index is constructed of cost measures such as union wage scales and materials and equipment prices. In addition, the AT&T and Turner indexes were also cost indexes. Altogether only about one-third of the constant-cost-2 index was based on construction price indexes. Owing to the lack of suitable alternatives, the index was still used in a number of growth studies, including Jorgenson and Griliches' (1967) well-known study of long-run productivity growth.

Dacy (1964, 1965) proposed an entirely different method of deflating construction. Dacy simply assumed that real construction output was proportional to real construction materials:

$$\frac{C}{P^c} = \frac{M}{P^m}, \tag{2}$$

where C and M are indexes of nominal construction and nominal materials, P^c is a construction price index and P^m is a materials price index. Equation (2) may be rewritten in a form similar to the one used by Dacy:

$$(3) \qquad P^{c} = P^{m}/b,$$

where b is an index of the share of nominal materials in nominal construction. The Dacy index therefore required only a price index for materials and an estimate of the share of materials in construction. The construction price index would equal the materials price index if there was no change in the materials share. An increasing share of materials in construction output would indicate that the price of materials is increasing faster than the price of other inputs. Hence in this case the construction price index would be lower than the materials price index.

There are two major problems with Dacy's method, one practical and one theoretical. Despite its simple appearance, the Dacy index is surprisingly difficult to estimate. The main problem is estimating the materials' share of output. Present data on materials production does not distinguish between construction and nonconstruction usage and is thus not comparable to the construction expenditure series. Alternatively, one could calculate the materials' share of output as one minus the value-added share. But here again the value-added and expenditure series are not comparable since the latter series also includes force account construction.

The second problem is more fundamental. Dacy's method is equivalent to assuming a fixed proportions Leontief technology in which there is no possibility of substitution between materials and other factors of production. In practice, contractors may substitute for on-site labor and capital by using prefabricated materials or by switching to more materials-intensive types of construction. Increased use of prefabricated materials would not represent a proportional increase in output, as assumed by Dacy, but would instead represent less on-site production. A long-term trend toward prefabrication would thus bias Dacy's index downward. This bias is small if the elasticity of substitution between materials and on-site factors is low, but increases exponentially as the elasticity approaches minus one.[9] On the other hand, Dacy's index would be biased upward if the relative price of materials rose. This seems to be the likely case after 1973, when materials prices increased rapidly but construction wage inflation was moderate.[10]

Gordon (1968) created an alternative construction deflator using a modified version of the Dacy index, the FHWA index, and a third index that he called the component-price hybrid (CPH).[11] To construct the CPH index, Gordon first averaged the ICC, FHWA, and Bureau of Reclamation indexes of the price of structural steel and structural concrete in place. He then compared these prices indexes to cost indexes for the same items and applied this ratio to the entire building sector. Algebraically, this may be written as:

$$(4) \qquad \text{CPH} = CI^{c}\,(P^{ss}/CI^{sc} + P^{ss}/CI^{ss})\,/\,2,$$

where CI is a cost index, P is a price index for materials in place, and the superscripts c, sc, and ss refer to all building construction, structural concrete, and structural steel, respectively. Gordon averaged the CPH and Dacy indexes to form a deflator for buildings. His nonbuilding deflator was an average of the Dacy and FHWA indexes.

The CPH was probably the most interesting feature of Gordon's index. The ratio of the price indexes for steel and concrete to their cost indexes will reflect changes in productivity, profit margins, and any other factors that cause price and cost indexes to differ. Thus the CPH assumes that productivity in steel and concrete construction is the same as for construction as a whole. One possible bias that Gordon suggests is that "concrete and steel may have been unusually suitable for mechanization, and efficiency improvements may have been less rapid in other components" (Gordon 1968, 422). Still, Gordon's method seems preferable to the assumption of no productivity change made by most of the indexes in the BEA I composite.

After a long hiatus, construction deflation has recently received renewed attention. This interest was motivated by the large unexplained fall in construction productivity during the late sixties and seventies. Allen (1985) estimated that about half of the construction productivity decline was due to an overdeflation of construction output. Allen accepted the BEA's use of the census index to deflate residential construction but made two adjustments to the nonresidential deflator. First, he replaced the nonresidential building deflator with a price per square foot index. Allen also used the urban portion of the FHWA index to deflate highways on the assumption that the rural portion was biased upward due to the decline in interstate highway construction. Allen deflated the remainder of the nonbuilding sector by an average of the urban highway price index and the building price per square foot index.

A crucial assumption of Allen's index is that square feet is a good proxy for output.[12] The price per square foot index is almost certainly biased upward since, as Allen notes, "there is no adjustment for likely increases in amenities or improved design" (Allen 1985, 668). In addition, building mechanical and electrical systems have become more sophisticated over time. A square foot index seems particularly unsuited for institutional buildings since these buildings have a very high concentration of amenities.

In earlier work (Pieper 1989a) I also used a price per square foot index to deflate nonresidential buildings, but one based on the more homogeneous category of office buildings. Residential construction was deflated with an index that removed the very largest category of homes, those over 2,400 square feet. This category of houses is the most amenity intensive and therefore the least suitable for a square foot based index such as the census. For the post-1973 period, we used a simple price per square foot index of homes less than 2,400 square feet. This is likely to be upward biased because it again does not adjust for other quality improvements. For example, houses have become more energy efficient and are more likely to include extras such as appliances and landscaping.[13]

We also adjusted the FHWA index for the size of highway contracts. The average size of high contracts has fallen in half in real terms since 1972, reflecting a decline in large interstate projects and a shift from new construction to reconstruction and repair projects. The effect of this shift was estimated from a 1981 cross-section regression of highway construction prices. The nonbuilding index was then an average of the adjusted FHWA index and the bid price components of the Bureau of Reclamation index.

Table 8.5 summarizes the methodology of the deflators while table 8.6 lists their rates of growth over the 1963–82 period. The BEA constant-cost-2 and Allen indexes increase at about the same rate as the BEA index. However this does not really provide support for the BEA composite since the constant-cost-2 deflator is based mainly on cost indexes, while a major portion of the Allen index, the building price per square foot index, is almost certainly biased upward. Indeed, nonresidential building square footage costs increased 2.6% faster per year than the BEA deflator in the 1947–63 period (Otelsberg 1972), which is a much faster relative rate of increase than after 1963.

Table 8.5 Summary of the Alternative Construction Deflators

Index	Description
1. BEA constant cost 2	
Nonresidential buildings	Unweighted average of the Turner and AT&T building cost indexes, FHWA composite, and BR indexes for power plants and pumping plants.
Nonbuilding	Weighted average of the FHWA, BR, AT&T, and ICC indexes, with heaviest weight on the BR index.
2. Dacy	Assumed real construction output was proportional to real construction materials usage.
3. Gordon	
Buildings	Unweighted average of Dacy's index and the "component price hybrid," an index based on the bid price components of the FHWA and BR indexes.
Nonbuilding	Unweighted average of Dacy's index and the FHWA index.
4. Allen	
Residential	Census index.
Nonresidential buildings	Index of the price per square foot of all nonresidentical buildings.
Highways	FHWA urban highway construction price index.
Other nonbuilding	Average of the nonresidential price per square foot index and urban portion of the FHWA index.
5. Pieper	
Residential	Price index of houses less than 2,400 square feet.
Nonresidential buildings	Index of the price per square foot of commercial buildings.
Nonbuilding	Average of the bid price components of the BR index and the FHWA index adjusted for contract size.

Note: Abbreviations used: BR = Bureau of Reclamation construction price index; FHWA = Federal Highway Administration highway construction price index; ICC = Interstate Commerce Commission railroad construction price index

On the other hand, the other three alternative indexes increase between 0.5% and 0.8% less per year than the BEA index. The Dacy index is probably downward biased in the 1963–72 period when the relative price of materials was decreasing but upward biased after 1972 when the opposite was true. The Gordon index indicates no bias in the 1963–72 period but an upward bias of almost 1% per year in the 1972–82 period. As mentioned previously, the Gordon index would be biased downward if concrete and steel productivity has increased more (or decreased less) than average construction productivity. However, a potentially much larger upward bias is that the FHWA index, a major input to the Gordon index, is upward biased due to the completion of the interstate highway system. Pieper's index is likely to be very conservative since it assumes no quality change per square foot in either office buildings or single family homes.

In conclusion, the preponderance of evidence indicates an overdeflation of new construction of at least 0.5% per year between 1963 and 1982. While a

Table 8.6 **Annual Rates of Change of Alternative Construction Deflators, 1963–82**

	1963–82	1963–72	1972–82
1. Total Construction:			
BEA	7.0	4.9	9.0
BEA constant cost 2[a]	7.1	5.5	8.6
Dacy[b]	6.2	3.6	8.5
Gordon	6.5	4.8	8.2
Allen	7.3	4.3	10.0
Pieper	6.3	4.2	8.2
2. Residential construction:			
BEA	7.0	4.4	9.4
Gordon	6.5	4.8	8.1
Allen	6.9	4.1	9.5
Pieper	6.5	4.2	8.7
3. Nonresidential buildings:			
BEA	7.0	5.3	8.6
BEA constant cost 2	7.3	5.7	8.6
Gordon	6.5	4.8	8.1
Allen	7.8	4.1	11.4
Pieper	6.2	3.9	8.3
4. Nonbuilding construction:			
BEA	7.1	4.9	9.0
BEA constant cost 2	6.9	5.0	8.6
Gordon	6.6	4.6	8.4
Allen	7.0	4.8	9.0
Pieper	6.1	4.4	7.6

Source: See appendix.
[a]Deflator for private nonresidential construction only.
[b]Not available separately by type of construction.

0.5% annual overdeflation may appear to be modest, if true, it would have major consequences. Construction productivity growth would be understated by roughly twice this amount because of the BEA's double deflation technique for measuring real construction value added. Investment would also be understated. Relative to 1963, gross private domestic investment would be larger by about 1% of GNP, which would substantially weaken the conventional argument that there was an investment slowdown in the seventies.

8.3 Improving the Construction Deflators

Most construction price indexes price intermediate units of output termed components. The price indexes can be divided into three types according to their method of pricing components. This section discusses the strengths and weaknesses of each method and speculates about their most promising applications. The section ends with some comments about cost indexes.

8.3.1 Bid Prices

In many types of heavy construction, contractors bid separately on each item specified in the contract. It is then relatively straightforward to construct a price index by averaging winning bids on the most important components. When individual components are not bid on separately, the contract bid price can still in principle be used to form a price index if there is some output measure available such as square feet. The main difficulty with bid price indexes is identifying a relatively homogeneous physical measure. Where heterogeneity occurs, the price index will be biased when quality change occurs within the component categories.

The FHWA index is usually considered a successful application of the bid-price method. However, a closer examination of this index reveals that its components are far from homogeneous. The FHWA publishes average bid prices by state for each of its six components. Since there are anywhere from five to 150 contracts per state, much of the price variation on individual projects has already been removed. Yet the average state prices still vary enormously, certainly by more than can be attributed to regional cost differences. For example, in 1981, average state excavation prices ranged from $0.78 to $15.71 per cubic yard (U.S. Department of Transportation, Federal Highway Administration 1982). The standard deviation of average state prices for the most homogeneous components, bituminous concrete, and reinforcing steel, is still about two times greater than the standard deviation of state construction costs.[14]

The BEA military price index attempts to solve the heterogeneity problem by first grouping construction into a number of narrowly defined categories based upon Department of Defense "performance specifications." For example, barracks are categorized by the number of bathrooms and permissible noise transmission levels. The category is then deflated by a price per square foot index. A similar procedure may be possible for some types of nonresidential buildings if they can be narrowly categorized. However, in general the potential use of bid prices seems somewhat limited due to the lack of homogeneous measures of construction.

8.3.2 Hedonic Price Indexes

Hedonic price indexes may be considered a type of component pricing where the component prices are estimated from a cross-section regression. The successful development of the census index lead to the hope that the construction deflation problem could be solved through the widespread use of the hedonic technique. However, census experiments with a hedonic price index for the multiunit residential sector have been largely unsuccessful (Pollock 1984) and little work has been done for other types of construction.[15]

In practice hedonic price indexes usually include only physical characteristics such as size and ignore quality characteristics such as design, materials and construction quality, and building amenities. It is therefore not surprising that hedonic indexes for buildings often differ little from price per square foot indexes. Figure 8.1 plots the annual percentage change in the census index and the percentage change in the price per square foot of new houses. With the exception of 1972 and 1973, the two series move virtually in tandem. The mean absolute difference between the annual census inflation rate and the per-

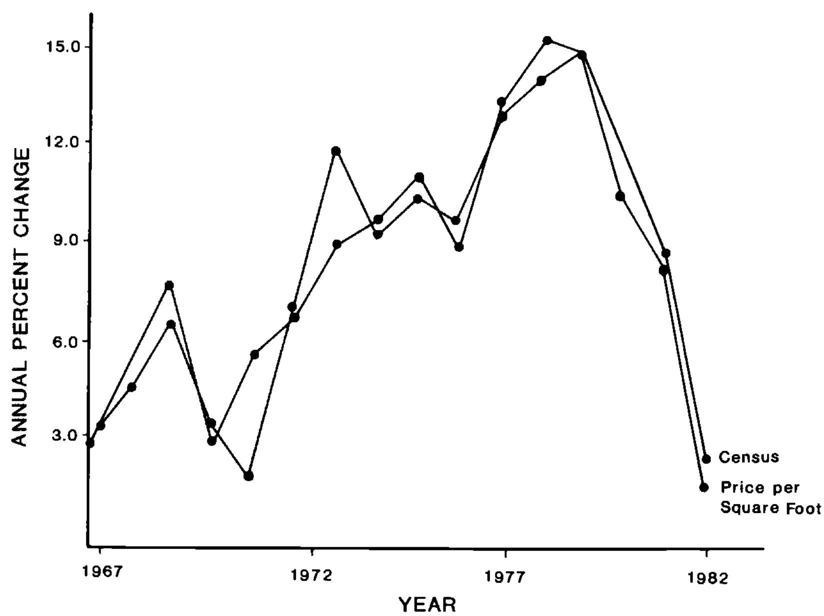

Fig. 8.1 Annual rates of change of the census index and an index of the price per square foot of single-family homes, 1967–82

centage change in the price per square foot is only 0.8%, while the mean difference is 0.3%.

The main weakness of hedonic price indexes is therefore the difficulty of quantifying many construction characteristics. For example, building design and the quality of materials are two very important factors which are extremely difficult to quantify. One of the problems with the experimental multiunit residential index is that only three characteristics (region, square feet, and number of bathrooms) were quantified. In addition, square feet appears to be a more homogeneous measure for houses than for apartments and nonresidential buildings.[16] Therefore the success of the census index may not be easily repeated for other types of buildings. Finally, hedonic price indexes require a significant number of observations, which can be a problem for smaller construction sectors. Lack of observations was a problem even in the relatively large multiunit residential sector for quarterly time periods.

One promising area for the hedonic technique may be highway construction. As shown earlier, the units priced by the FHWA index are not very homogeneous. Quantifiable characteristics such as the division of construction between interstate and noninterstate, rural and urban, and new and reconstruction projects may be able to explain some of the price variability. In addition, the FHWA awards over 2,000 large (greater than $500,000) contracts a year, so lack of observations would not be a problem.

8.3.3 Estimation Indexes

This method uses estimates from contractors, cost engineers, or other types of "informed judgment." A typical estimation index would survey firms and ask them to estimate the cost of constructing a hypothetical project with fixed specifications. The respondent may be asked to price the entire project or the project may be divided into components, with each respondent estimating only the price of a particular component.

Although deflation by estimation indexes is rare, there are a few precedents. The FHA 70-cities index, which forms half of the BEA's residential deflator for the 1947–63 period, was based on a survey of single-family home contractors. The FERC has received courtesy bids on a hypothetical pipeline project from three companies since 1972. This information is given a small subjective weight in the FERC index.

Statistics Canada uses the estimation approach to construct a price index for nonresidential buildings. In contrast to the FERC and FHA 70-cities indexes, which priced the entire structure, Statistics Canada uses a disaggregated approach, dividing a building into its component operations. Statistics Canada first selects prototype models of five types of nonresidential buildings: an office, warehouse, small shopping center, light industrial building and high school.[17] The construction of each building is divided into five main categories: architectural, structural, mechanical and electrical trades and the general contractor's overhead and profit. Representative items for each category are priced, mostly on the basis of surveys of subcontractors. The architectural and structural items generally refer to a specified quantity of materials in place and thus reflect all construction costs. The mechanical and electrical trades are deflated using more of a cost-based approach. In these trades, materials are deflated by conventional materials price indexes while labor costs are deflated by wages adjusted for productivity on the basis of a subcontractor survey. Roughly 100 different items are priced for each building type.

The obvious advantage of estimation indexes is that they can control for construction heterogeneity by keeping the specifications fixed over time. Their main weakness is that they are based on hypothetical prices rather than on actual transaction prices. Contractors submitting hypothetical bids know they will not be required to construct the project in question. They also do not have the normal incentive of bidding as low as possible in order to win the contract. Under these conditions, they may bid differently than they would on an actual project.

There is some evidence that construction estimates are insensitive to changes in competitive conditions. Both the Federal Highway Administration and the Bureau of Reclamation have engineers estimate the cost of a project before its contract is awarded. The engineer's estimate, therefore provides a measure of informed judgment that is likely to be similar to that provided by a survey of contractors. The actual contract cost varies from 76% to 111% of the engineer's estimate over the 1977–86 period. What is most striking about this ratio is its procyclical behavior. Actual bid prices fall much more in recessions than the estimates and rise more rapidly in expansions. This can be clearly seen in figure 8.2, which plots the ratio of the low bid to the engineer's estimate against the ratio of actual to trend construction employment. The simple correlation coefficient between the employment ratio and the low bid ratio is 0.76 for the Federal Highway Administration and 0.72 for the Bureau of Reclamation.

Engineers' estimates thus tend to be more "sticky" than actual prices and may thus measure short-run price movements poorly. To quantify this, the FHWA index was compared to a highway price index based on the engineer's estimates.[18] The mean absolute difference between the semiannual percentage change in these two indexes, expressed at an annual rate, was 4.4%. This compares to a mean absolute percentage change in the FHWA index of 9.2%. There are a few cases where the discrepancy between the two indexes is very large, such as in the second half of 1980, when the estimated prices rose by 15% but actual prices fell slightly. On the other hand, the FHWA index is unusually sensitive to competitive conditions because it is based on auction prices. It may thus exaggerate the insensitivity of estimation indexes.

The Stigler committee considered the problems with construction estimates so severe that it recommended that they be used "only as a last resort" (NBER 1961, 90). However, this is probably too harsh a judgment. Since the specifications of a hypothetical project are held fixed over time, an estimation index

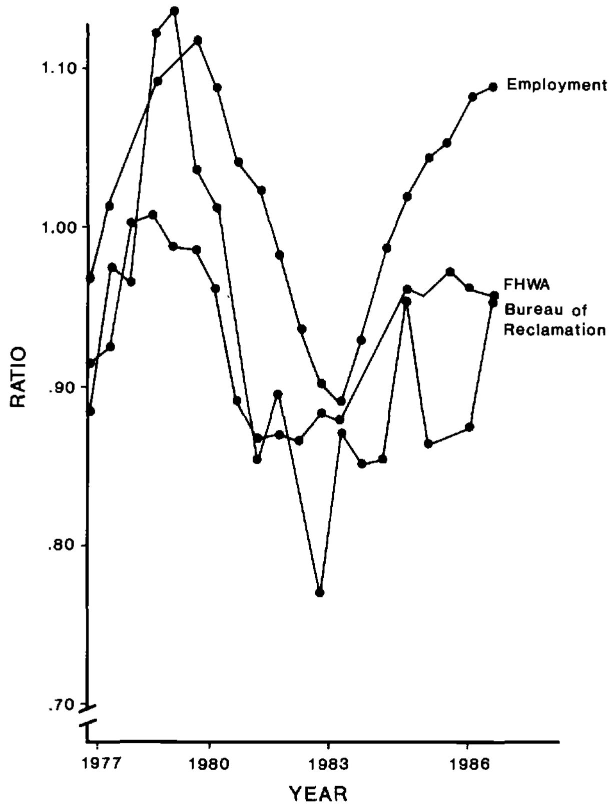

Fig. 8.2 Ratio of low bid to engineer's estimate, FHWA, and BR indexes, and ratio of actual to trend construction employment

controls for construction heterogeneity, and thus quality change, better than other methods. Its weaknesses in measuring short-run price movements must then be balanced against its strength in measuring the long-run trend. This type of deflation would seem especially appropriate for very heterogeneous types of construction such as institutional buildings and utilities. Furthermore, the problem of price stickiness may be reduced by carefully questioning the estimators. Statistics Canada's index for overhead and profit is very volatile, and, as a result, its overall index appears to be more sensitive to changes in competitive conditions than conventional construction price indexes.

A few other comments on estimation indexes are in order. First, there is no obvious method of weighting the responses when several contractors are surveyed. If the project was real, then only the low estimate would be relevant. However, since the project is hypothetical, the low estimate may be a statistical outlier that should be ignored. The FERC therefore uses an average of its courtesy bids while Statistics Canada makes a judgmental decision on which estimate to use. Second, estimation indexes require a significant amount of cooperation from contractors since it takes time and effort to make a realistic estimate, especially on more complex projects. Statistics Canada has been able to increase contractor cooperation by using people with a background in the construction industry as quantity surveyors.

Finally, there are two types of estimation indexes, each with its own advantages. The first type prices the entire structure, while the second type prices the structure's components. The advantage of the first type is that the estimated price will reflect the services of the general contractor, whose functions are very difficult to price separately. However, since some types of structures are very heterogeneous, the respondent may have no practical experience in pricing the structure in question. Dividing the structure into its simpler component operations would increase the likelihood that the respondent has actually performed work on a similar project. Thus it would appear that the disaggregated approach would be best for complex types of structures while the aggregate approach would be best for simpler structures.

8.3.4 Cost Indexes

Cost indexes are obviously the least desirable method of deflation. However, cost indexes are also the simplest and least expensive indexes to construct and will be continued to be used by the BEA in the foreseeable future. This section simply makes the point that cost indexes for the same type of construction can differ widely depending upon their weights and data sources.

A large number of cost indexes use cost data published by the *Engineering News-Record* (ENR), a trade publication. This data often differs significantly from government estimates for the same items. For example, ENR publishes a construction cost index that is a weighted average of union wage rates and the price of lumber, steel, and cement. This index is presently used by the BEA to deflate telephone construction. As a comparison, a cost index with identical weights for the same items was constructed using the Bureau of Labor Statistics (BLS) producer price indexes and a BLS index of union wages.[19] Despite their identical methods, the BLS index increases about 0.7% less per year between 1963 and 1982. The main source of the discrepancy is the ENR wage measure, which increases 1.3% faster per year than the BLS measure. On the other hand, ENR materials prices increased 0.5% per year less than the BLS producer price indexes. However, the materials price indexes differ greatly among the 20 individual cities for which ENR publishes data. For example, ENR estimates the increase in lumber prices between 1967 and 1982 as 61% in Chicago but 250% in Cleveland. Such large differences hardly instill much confidence in the reliability of the ENR data.

The EPA sewer construction cost index is also based on ENR data. The EPA index is actually an average of two indexes, one representing sewer lines and the other sewage treatment plants. Table 8.7 calculates cost indexes for both types of construction using the same weights as the EPA but with BLS

Table 8.7 Cost Indexes for Sewer Construction

Index	1982 Index Level (1967 = 100)	Annual Rate of Growth, 1967–82
1. EPA sewer lines construction cost index	341.7	8.5
2. BLS sewer lines cost index—EPA weights:		
a. Based on industry wages	338.4	8.5
b. Based on union wages	330.5	8.3
3. BLS sewer lines cost index—BLS weights:		
a. Based on industry wages	309.7	7.8
b. Based on union wages	317.6	8.0
4. EPA sewage treatment plant construction cost index	348.9	8.7
5. BLS sewer plant cost index—EPA weights:		
a. Based on industry wages	314.3	7.9
b. Based on union wages	305.9	7.7
6. BLS sewer plant cost index—BLS weights:		
a. Based on industry wages	302.4	7.7
b. Based on union wages	310.4	7.8

Source: See appendix.
Note: Lines 2 and 4 calculate the EPA cost index with BLS data used in place of *ENR* data. Lines 3 and 6 do the same except the data is weighted by a BLS study of sewer construction.

price and wage data. Because unionized construction declined during the seventies, a union wage index may overstate the increase in labor costs. Therefore table 8.7 uses two wage series, one based on union wages and one based on average construction industry wages. The substitution of BLS data for ENR data has little effect on the sewer line index but it lowers the rate of increase of the treatment plant index by about 1% per year over the 1967–82 interval.

The EPA index weights the different inputs based on a study of sewer construction during the 1956–62 period. A more recent study was undertaken by the BLS in 1971 as part of its series on materials and labor requirements in construction. Lines 3 and 6 of table 8.7 recalculate a sewer cost index using BLS data weighted by the BLS 1971 study. Both sewer indexes increase significantly less than the EPA index over the 1967–82 period. A closer inspection of the EPA index weights reveals a few anomalies. For example, the sewer line index gives structural steel an enormous weight of 50% in the materials portion of the index. The reason for the large weight is that EPA used structural steel as a proxy for the price of construction equipment. Since the relative price of steel rose during this period, this contributed to the fast rise of the EPA index.

Given that cost indexes for the same type of construction may differ significantly, it should go without saying that if cost indexes must be used for deflation, then they should at least have recent weights and reliable data sources. The presumption here is in favor of public data sources over private data sources such as ENR. The former, but not the latter, must pass some level of statistical standards before they are published. However cost indexes frequently use private data sources. No less than five of the indexes in the present BEA composite use some ENR data: the EPA, FERC, Bureau of Reclamation, and Handy-Whitman indexes and the ENR index itself.

8.5 Conclusion

The BEA still relies heavily on cost indexes and proxy indexes to deflate construction output. Price indexes are available for only two major construction sectors, single-family homes and highways. Partly as a consequence, it seems likely that the BEA deflator for new construction has a significant upward bias in the 1963–82 period.

This paper will close with two general observations. First, progress in construction deflation has been made in the past when there has been interaction between government statisticians and the academic profession. The harsh criticisms of the commerce indexes by the Stigler committee and other academics in the sixties lead to a demand for better statistics, which spurred changes in deflation by the BEA. Similarly the profession's lack of interest in the area in the past decade has abetted an inactivity by government. Second, there is probably no single best method for deflating construction. Each method has its strengths and weaknesses, the relative amounts of which will vary by the type of construction. With a few minor exceptions, the estimation approach has not been used in the past because it is not based on transaction prices. However, given the heterogeneity of many types of construction, it appears that some type of estimation indexes are necessary if reliance on cost and proxy indexes is to be reduced.

Appendix

Sources and Methods for Selected Tables and Figures

Tables 8.1 and 8.2

The sources for the three deflation methodologies are the NBER (1961), U.S. Department of Commerce, Bureau of Economic Analysis (1974), and my conversations with BEA staff members. Published accounts of recent BEA deflation changes may also be found in the July issues of the *Survey of Current Business*. The value of new construction expenditures, rounded to the nearest $100 million, may be found in table 5.4 of the U.S. Department of Commerce, Bureau of Economic Analysis (1986). I have used an unpublished version of table 5.4 that shows construction expenditures in millions of dollars. The hybrid Bureau of Reclamation and FERC indexes are weighted by their price index percentage, 32% and 65%, respectively, when calculating the percentage of construction expenditures deflated by price indexes. The percentage of construction deflated by proxy indexes is calculated by dividing construction into the following 19 sectors, corresponding roughly to the breakdown in table 5.4 of the national income accounts: single-unit residential, multiunit residential, additions, alterations and replacements, industrial, office, other commercial, institutional and other buildings, telephone, railroad, electric utilities, gas, petroleum pipelines, nonresidential farm, highways, military, conservation and development, sewer, water, and other private and public. The CPI maintenance and repair index is assumed to be representative of the additions, alterations, and replacements sector.

Table 8.3

The methodology for the three composites and the source of the expenditure weights are listed above. The individual indexes that constitute the composite are taken from a variety of sources. The following indexes are taken from the July/August 1983 issue of *Construction Review:* American Appraisal, Boeckh, Engineering News-Record, FHWA, Bureau of Reclamation, Turner, Handy-Whitman buildings and electric power, AT&T, and FERC. The census and BEA military price indexes are from lines 25 and 39 of table 7.12 of U.S. Department of Commerce, Bureau of Economic Analysis (1986). The CPI maintenance and repair is from U.S. Council of Economic Advisers (1986, table B-56), the Fuller index is from *Engineering News-Record* (various issues), and the EPA index is from the U.S. Environmental Protection Agency (1983). Four of the BEA I component indexes are not available for the entire 1963–82 period. The ICC, Associated General Contractors, and U.S. Department of Agriculture indexes were discontinued in 1967, 1971, and 1973, respectively. The Handy-Whitman gas index, while still compiled, is not publicly available after 1974. Values for these four indexes until their date of discontinuance are taken from *Historical Statistics of the United States* and *Statistical Abstract of the United States.* The ICC railroad and telephone indexes are extrapolated from their date of discontinuance to 1982 by the FHWA and AT&T indexes, respectively. The Handy-Whitman gas index is extrapolated by an average of the Handy-Whitman building and electric utility indexes. The other two indexes are extrapolated by cost indexes using a methodology as close as possible to that of the original indexes. The Department of Agriculture index is extrapolated by an average of the producer price index for construction materials (U.S. Council of Economic Advisers 1986, table B-60) and an index of wages for farm labor (table B-96), using weights of 78% and 22%. The Associated General Contractors index is extrapolated by the cost of five types of materials and two types of labor, using weights found in the U.S. Department of Commerce, Bureau of the Census (1964) and cost indexes published in the July/August 1983 issue of *Construction Review.* The above extrapolations will have very little effect on the overall composite because the four indexes together have a weight of only about 10%.

Table 8.4

The BEA composites are fixed weight deflators using 1982 expenditure weights. Sources for the indexes used in table 8.4 are listed in the appendix description of table 8.3. The gap variable is defined as the difference between actual and trend construction employment as a percent of trend. Trend construction employment is calculated as the predicted value of a 1963–82 regression of the log of construction employment (U.S. Council of Economic Advisers 1986, table B-40) against a time trend. A weighted least squares procedure, with weights based on the regression standard errors, is used when testing for the equality of coefficient b_2 between regressions.

Table 8.6

BEA: The BEA index is a fixed-weight price index using 1982 expenditure weights. The index refers to the present published deflator, which is a combination of different deflation methods that have been linked together in the past. It will thus differ slightly from the BEA III composite which uses one method continuously throughout the 1963–82 period. The source for expenditures and prices by type of construction is *The National Income and Product Accounts of the United States, 1929–1982,* tables 5.4 and 7.12. The BEA's published price index for all structures includes the following nonconstruction items: brokers commissions, mining exploration, shafts and wells, and mobile homes. The structures price index will thus differ from the index for total construction shown in table 8.6, which excludes these items.

BEA constant cost 2. The methodology of the BEA constant-cost-2 index is described in U.S. Department of Commerce, Bureau of Economic Analysis (1971). The source of the individual components of the Bureau of Reclamation index is the U.S. Department of Interior (1984). The sources for the other indexes are listed under the description for table 8.3

Dacy. The Dacy index is calculated using the producer price index for construction materials (U.S. Council of Economic Advisers 1986, table B-60). The share of materials is calculated as materials costs divided by the cost of materials plus labor. Data are from the 1967, 1972, and 1982 Census of Construction, U.S. Summary, table B-1 (U.S. Department of Commerce, Bureau of the Census 1985). The materials share is extrapolated back to 1963 on the basis of the percentage of intermediate inputs in total new construction in the 1963 and 1967 input-output tables.

Gordon. Gordon's version of the Dacy index uses the same sources listed above. The only difference between the two versions is that Gordon calculated the material's share as materials cost divided by output. The price of structural steel in place is from the Federal Highway Administration (1983). The price of structural concrete in place is an average of prices from U.S. Department of Transportation, Federal Highway Administration (1983) and the Bureau of Reclamation (unpublished information from the Construction Support

Branch). The Gordon CPH index originally also used the ICC index and the Bureau of Reclamation index for steel bridges. The former has been discontinued while the latter is not used here because it is in fact a materials price index. The cost index for steel and concrete in place is formed by averaging wages for highway construction (U.S. Department of Labor, BLS 1985) and producer price indexes for ready-mix concrete (*Construction Review* [July/August 1983]) and structural steel (PPI code 1013–0245). The steel and concrete cost indexes use 1963 materials and labor weights for highway construction (U.S. Department of Transportation, Federal Highway Administration 1975). The cost index for all construction is a weighted average of the producer price index for construction materials and the average hourly earnings of construction workers (U.S. Council of Economic Advisers 1986, table B-41). Labor and material weights are from the 1967 Census of Construction, U.S. Summary, table B-1.

Allen. The urban highway price index for the years 1968–82 is published in the Federal Highway Administration (1983). The urban price index is not available before 1968 and is therefore extrapolated back to 1963 by the FHWA composite index. The source for nonresidential building square feet and contract value is the *Statistical Abstract of the United States.* The residential price index is from table 7.12, line 25 of the *National Income and Product Accounts of the United States, 1929–82.*

Pieper. The census index used nine dummy variables to characterize house size in the 1963–73 period. The residential price index for these years is calculated by simply excluding the dummy variable for houses over 2,400 square feet, reweighting the remaining size categories to sum to one and then using the census Laspeyres index formulation. The regression coefficients are unpublished information provided by the Bureau of Census, construction statistics division. Index weights are published in U.S. Department of Commerce, Bureau of Census, *Price Index of New One-Family Houses Sold,* 1973. Average sales prices for houses in six different square foot categories are published in the Bureau of the Census, *Characteristics of New Housing,* table 22. The residential index for 1973 onward is a weighted average (using number of houses as weights) of sales price indexes for the five size categories under 2,400 square feet. Finally, the residential index is adjusted for land costs by applying the ratio of the census index excluding land to the index including land. The price per square foot of contracts for new office buildings in the 1963–68 period is from Musgrave (1969). This index is extended to 1971 using an index for commercial buildings found in Otelsberg (1972). Contract value and square feet for office building contracts is published in the November issue of *Architectural Record* for 1971 onward. The price per square foot values refer to new contracts and not construction in place. A price index for construction in place is calculated by taking a three-year moving average of the index for new contracts, using weights of 31%, 56%, and 13%. These weights are based on a F. W. Dodge study of progress patterns (U.S. Department of Commerce, Bureau of the Census, 1970). The bid price components of the Bureau of Reclamation index are unpublished data from the Construction Support Branch of the Bureau of Reclamation. The adjusted FHWA index is calculated as

$$\ln P^* = \ln P - .2 \ln \text{size}, \quad (1)$$

where P^* is the adjusted index, P is the FHWA composite, and size is average real contract size. The coefficient of .2 is based on a 1981 cross-section regression (Pieper 1989a). Average contract size is from the U.S. Department of Transportation, Federal Highway Administration's "Bid Opening Report."

Table 8.7

The source for the methodology of the EPA index is the Federal Water Pollution Control Administration (1967). The EPA indexes price labor and 10 types of materials. Lines 2 and 5 price the same items but use BLS producer price indexes and BLS wage series. The BLS union wage index is from *Construction Review,* table E-3. Because the series ended in 1981, it was extrapolated to 1982 using average construction industry wages. The industry wage series is the average hourly earnings for construction workers (U.S. Council of Economic Advisers 1986, table B-41). Lines 3 and 6 show cost indexes for sewer construction using the above-mentioned BLS wages series and producer price indexes for 27 types of materials with weights taken from U.S. Department of Labor, Bureau of Labor Statistics (1979). (Details of the items priced are available from the author on request.)

Figure 8.1

The census price index including land is from the U.S. Department of Commerce, Bureau of the Census, *Price Index of New One-Family Houses Sold.* The price per square foot index is calculated as the average sales price of new one-family houses sold divided by average square feet. Both series are taken from the Bureau of the Census, *Characteristics of New Housing.*

Figure 8.2

The source of the ratio of bid to engineer's estimate is the U.S. Department of Transportation, Federal Highway Administration, "Bid Opening Report," and the U.S. Department of the Interior, Bureau of Reclamation, "Construction Cost Trends." See appendix description of table 8.4 above for a discussion of the ratio of trend to actual employment.

Notes

1. The term input-cost index is also used in the construction literature to refer to an average of input prices. However, I use the term cost index because the term input-cost

is also used in the price index literature to convey a different meaning, namely the cost change of inputs required to produce some constant level of output.

2. For example, the American Appraisal index made an adjustment based on a survey of contractors on the productivity of workers in a few specific crafts. The AT&T outside plant index simply assumed 2% productivity growth in the 1967–81 period. The reason that arbitrary or subjective methods are used is that cost indexes do not measure output and thus cannot measure productivity changes directly.

3. The Commerce Department had previously published an average of six cost indexes but had not used them as deflators.

4. The term composite is used here to refer to a deflator for total new construction based on BEA methodology. The Census Bureau also publishes a composite construction price index but it differs in a few respects from the BEA measure.

5. The Census Bureau originally entered floor space in the regression by using dummy variables for nine different size categories. Beginning in 1974, floor space was entered as a continuous variable. The census also added two other variables, fireplaces and lot size, to the regression in 1974.

6. A major part of the BEA II and BEA III composites, the census index, is only available beginning in 1963. Two important components of the BEA I composite, the American Appraisal and Fuller indexes, were discontinued in the early eighties.

7. I use total construction employment to measure activity in the residential and nonresidential sectors. It would be desirable to have a measure of economic activity for each of the sectors but construction employment by sector is only available beginning in 1972.

8. See Foss (1961) for an earlier discussion of the sensitivity of the FHWA index.

9. This assumes an inelastic rate of substitution between materials and on-site factors of production. The Dacy index would be downward biased if the rate of substitution between materials and on-site factors is elastic. See Pieper (1984) for details.

10. The increase in the cost of on-site factors is not observable since it should be adjusted for productivity, an unknown. However, the increase in hourly construction wages between 1973 and 1982 was 81%, well below the 115% increase in materials prices. It seems unlikely that productivity decreases could account for the difference.

11. Dacy measured the materials share as materials divided by materials plus wages. He thus ignored non-labor components of value added. Gordon measured the parameter b as the materials share of nominal construction output.

12. See Pieper (1989b) for a critique of Allen's adjustments.

13. Unfortunately only a limited amount of information on housing amenities is available but the evidence strongly suggests increasing quality. The share of new houses with dishwashers increased by 58 percentage points between 1963 and 1982, while the share with stoves and refrigerators increased by about 10 percentage points in the same period. Real production of wood kitchen cabinets increased three times faster than real expenditures on new housing in the 1967–80 period. This suggests higher quality kitchens. Houses are also much more likely to include a full second bathroom rather than a half bathroom. As for energy efficiency, the percentage of new homes with double-glazed windows increased from 25% in 1974 to 54% in 1982. Eighty-four percent of all new houses built after 1975 have wall insulation, compared with 54% of those built between 1950 and 1969. The source for these figures is Pieper (1984), chap. 3.

14. The standard deviation of the state bid-price means for bituminous concrete and reinforcing steel is about 20% of the mean of the state means (Pieper 1989a, 314). Cost indexes reported by Allen (1984) for 27 states and regions indicate a standard deviation of construction costs equal to 8.2% of the state means.

15. Hedonic price indexes for nonresidential buildings have been estimated by Allen (1984) and Shriver and Bowlby (1985).

16. Otelsberg (1972) reports that the standard deviation of the price per square foot of apartments and most types of nonresidential buildings is between 50% and 80% of the mean. In contrast, data from *Characteristics of New Housing* (U.S. Department of Commerce, Bureau of the Census 1982) indicate standard deviation of the price per square foot of single family homes of about 25% of the mean.

17. The models are based on actual buildings constructed. The weights of the different items are based on an analysis of the blueprints and bid documents. The material in this paragraph is drawn primarily from the author's phone conversations with D. S. Seymour of Statistics Canada.

18. The estimation index was calculated as the actual FHWA index divided by an index of the ratio of the engineer's estimate to the low bid.

19. The weights of the ENR index are given by the U.S. Department of Commerce Office of Business Economics (1956), para. 210. The source for both the materials prices and union wage rates is *Construction Review,* tables E-2 and E-3. The union wage rate series ends in 1981. It was extrapolated to 1982 on the basis of average hourly earnings of construction workers (U.S. Council of Economic Advisers 1986, table B-41).

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Comment Robert P. Parker

In "The Measurement of Construction Prices: Retrospect and Prospect," Paul Pieper reviews the past 40 years of development of the price indexes used by the Bureau of Economic Analysis (BEA) to prepare the constant-dollar structures (construction) components of GNP.

Pieper traces these developments, and the impact on them by academicians and by the staff of the Department of Commerce, and draws two major conclusions: "Progress in construction deflation has made in the past when there has been interaction between government statisticians and the academic profession"; and, "There is probably no single best method for deflating construction." It is difficult to quarrel with such general statements.

Pieper reviews four major types of price indexes available for the preparation of the constant-dollar construction estimates of GNP, evaluates their relative merits, and suggests some future directions for improvement. On indexes based on unit prices, such as price per square foot, Pieper sees very limited applications because it is difficult to identify a relative homogeneous physical measure. He indicates that the present Federal Highway Administration (FHWA) price index is defective because it treats all highway projects as homogeneous. On the use of hedonic price indexes, he is optimistic that they can be used for types of structures for which construction characteristics can be quantified and where there are a sufficiently large number of observations. He suggests that an effort be made to estimate a hedonic index for highway construction, using the detailed FHWA's data base. For contractor estimates, or the pricing of hypothetical structures, he seems to be favorably disposed if the work can be done properly. He observes, however, that previous efforts, except for those of Statistics Canada, have had too many shortcomings. Finally, he indicates that cost indexes are the least desirable type for deflation and expresses concern about the quality of the privately prepared cost data

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The views expressed are those of the author and do not necessarily reflect the opinions of the Bureau of Economic Analysis or any other members of its staff.

that are used to prepare many cost indexes. Later, I will review each of these types of price indexes and indicate how I think BEA should distribute its resources among them.

Pieper reviews developments at the Commerce Department, concluding that there has been little progress since 1946 when the department first published the Commerce Composite Construction Index. The only major steps forward, according to Pieper, were the development at the Census Bureau of the hedonic index for the sales price of single-family homes and the development at BEA of price indexes for military construction. The other changes appear to be minor improvements as BEA shifted from one proxy index to another with only slightly improved estimates. In addition, Pieper's analysis of differences over time of the various indexes shows that these changes had little quantitative impact. Pieper, however, does not discuss why there has been so little progress or why so many major deficiencies remain unresolved. He merely implies that the lack of progress reflects the slowdown in the interaction between those of us at Commerce and academic economists. I do not share this interpretation. BEA welcomes constructive criticism or new ideas from any source. Unfortunately, during the period covered in this paper, such help was minimal. In the 1960s, Dacy and Gordon each made thoughtful suggestions, but BEA reviewed them and concluded that they were no better than the measures used at that time. More recently, Allen and Pieper have suggested changes, but again nothing that one would consider a major improvement. Pieper also notes that the NBER's review of price statistics in 1961, which identified the problems with the indexes in use, did not result in proposals for an improvement program.

Pieper's observations on the sources of progress, or the lack thereof, are, in my opinion, incomplete. For example, he neglects to discuss the lack of support for improvements from interested parties in the private sector. The construction industry apparently lacks strong trade associations with an interest in statistical issues and influence in the U.S. Congress. There have been several studies on declining productivity in the construction industries that blamed part of the decline on the lack of adequate price indexes, but they failed to arouse any private-sector support for improvement. Such support for improved statistics usually is crucial to obtaining additional resources from Congress. For example, private-sector support appears to have been a major factor behind recent increases in funding for programs to improve the availability of statistics on services. The story of services also points to the need for some current policy issue within the government to rally support for the improved statistics. Services statistics became important because of international trade issues and issues relating to changes in the industrial composition of the domestic economy.

Pieper also did not recognize that BEA, which prepares the constant-dollar structures estimates, generally does not collect the source data it uses; that is, it is not the primary price statistics agency for the federal government and, in this regard, is limited in both resources and technical expertise to collect and compile price indexes. Pieper also does not acknowledge that the Office of Management and Budget (OMB), through its responsibilities in approving new surveys and in coordinating statistical policy in the federal government, is a major player in the development of federal statistics. Despite identification by BEA and others that these statistics were a major problem, OMB has not made improvement of construction price statistics a major goal; it could have done so either by establishing an interagency effort to resolve the problem or by initiating funding for improvements. In summary, by looking only at the Department of Commerce, Pieper has neglected several of the groups whose responsibility for improved construction price indexes is as great if not greater than that of academics or BEA.

Now let us turn from the past and look at the work that is underway at BEA and the Census Bureau on construction prices and what work is likely in the future. The Census Bureau, as Pieper reports, is developing a hedonic price index for multifamily housing. Early efforts have been hampered by the use of only a small number of characteristics; fortunately, other data items are available in the material already collected by the Census Bureau so that other alternatives can be tested. BEA is currently engaged in two major efforts, neither of which are discussed by Pieper. One effort involves working with the FHWA's highway cost indexes to compile price data on a put-in-place basis. The second effort is a comprehensive study of the quality of private construction cost/price indexes—including indexes that BEA has not previously worked with. This study will enable BEA to evaluate each of these indexes and to determine both their relative and absolute quality for use as price indexes in GNP. The results of this study may lead to some changes in price indexes used in deflation. As I have indicated, however, they are unlikely to be considered as major improvements as it appears that the private indexes all have at least one serious shortcoming.

After these efforts are completed, I would recommend that BEA look seriously at the contractor-estimates approach. This approach would consist of two elements. First, BEA would contract for the preparation of detailed specifications for several types of structures; the work would be done by private architectural or engineering firms or some similarly qualified group in another government agency. Second, a group of professional cost estimators with appropriate geographic distributions, again under contract, would price these structures at least once a year. This information would be used by BEA to compile price indexes for various types of structures to replace the currently used indexes for nonresidential buildings, both private and public. In addition, these same specifications would be used by BEA to develop cost indexes using various government price indexes. The cost indexes would serve both to cross-check the contractor estimates and to extrapolate them in the current period.

Although these efforts conflict with previous judgments about both of these approaches, they should be tried again. Contractor estimates prepared by professional cost estimators should provide very accurate information, especially if estimators are paid for their services. The use of hypothetical building specifications also seems reasonable, provided they are updated to take into account changes in technology. Pieper expresses several concerns about the contractor-estimate approach—it does not use transaction prices, it does not recognize competitive conditions, it does not use representative weighting, and it usually is based on poor responses. I believe that these concerns can be taken care of with a well-run program, just as Statistics Canada has been successful with a similar program.

As for continuing work on cost indexes, properly estimated cost indexes can be viewed as providing an upper boundary on price changes because there seems to be general agreement that cost indexes overstate true price increases as they fail to recognize changes in productivity or decreases in price resulting from competitive conditions. Another virtue of having well-constructed cost indexes is that they can serve as a means of testing the validity of price indexes derived using other approaches.

Pieper and others criticize cost indexes and construction estimates because of their insensitivity to short-run developments. Although such criticisms are likely to be valid for monthly or quarterly indexes, they are not likely to be valid when the indexes are estimated annually. Introduction of accurate annual price indexes should be BEA's major goal for improving construction prices. Finally, there seems little or no recognition by the critics of cost indexes that for "own-use" construction—that is, buildings where the owner is the builder—there is no difference between cost and price. This situation is very likely to be the case for a substantial part of industrial buildings.

The programs I have described will cost money, although BEA may be able to get some free assistance from private trade associations and government agencies in obtaining the detailed specifications for certain types of structures. The Business Roundtable, for example, for many years has expressed concerns about the government's construction statistics, and the National Bureau of Standards has a unit devoted to issues of building technology. The results of these programs, of course, will not be perfect, but I think their use will significantly improve the accuracy of the estimate of constant-dollar structures expenditures in GNP. Pieper's paper has been very useful to our ongoing evaluation of alternatives to improve construction prices. We look forward to his continued interest in this area and hope he can interest some of his academic colleagues to do likewise.

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