Multifactor productivity in the utility services industries

Growth in multifactor productivity in these industries slowed by 3.2 percent per year after 1973, according to a new BLS study; results also show the impact of energy price increases on the utility services industries, which are heavily dependent on fossil fuel inputs

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This article introduces a new BLS measure of multifactor productivity for the utility services industries, that is, electric, gas, and sanitary services.[1] The measure relates output to inputs of capital, labor, energy, materials, and purchased business services. By contrast, the previously available BLS labor productivity measure relates output to labor input only.[2] It is important to consider factors other than labor in measuring productivity for the utilities because capital, energy, and materials each account for a larger portion of utilities' total costs than does labor; thus, it is reasonable to expect the industry to strive for productivity gains in the use of these inputs. In particular, the heavy use of fossil fuels by utilities offers a unique opportunity to study the impact of past energy price increases on productivity.

After 1973, labor productivity growth slowed by 1.7 percent per year in the nonfarm business sector.[3] A much larger slowdown of 6.4 percent per year occurred in electric, gas, and sanitary services. This finding is consistent with the view that the productivity slowdown partly reflected rising energy prices. Given the extensive consumption of fossil fuels by electric and gas utilities, large increases in the relative cost of energy would be expected to alter the optimal mix of inputs in this industry. Moreover, passing on higher energy costs would tend to reduce demand for the industry's output, limiting some important sources of productivity growth. Capacity utilization could fall, compromising existing scale economies. But also, acquisitions of new plant and equipment could be delayed, along with any technical improvements associated with them.

It is important to know whether multifactor productivity growth, like labor productivity growth, has slowed significantly over the years. Average annual rates of growth in multifactor productivity are reported here for 1948 through 1988. Data for the pre- and post-1973 periods reveal the extent of the productivity slowdown in utility services industries. The multifactor productivity framework is also used to examine single-factor productivity ratios for inputs other than labor and whether they rose or fell following the energy price increases.

This article contributes to our understanding of productivity and costs in the services sector generally. For example, 12 percent of capital income in the nonfarm, nonmanufacturing sector of the economy accrued to utility services industries in 1988, and electric utilities have accounted for more than one-third of

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annual energy consumption in the United States since 1981.[4] Thus, examination of productivity gains stemming from these and other factors in utility services industries is an important component of an effort to understand multifactor productivity trends in services as a whole.[5]

Methodology

Measurement framework. Multifactor productivity is defined as output per unit of combined inputs of capital, labor, energy, materials, and purchased business services. Since multifactor productivity growth is being measured for a small group of industries in this study, it is important that intermediate inputs — energy, materials, and services — are explicitly included. Measures of productivity for large sectors of the economy may reasonably be defined in terms of real value-added output relative to labor and capital inputs. This is because most intermediate inputs are both produced and consumed within large sectors; therefore, intermediates would be counted as both inputs and outputs in gross output measures. It follows that value-added measures avoid double counting intermediate transactions. By contrast, for multifactor productivity measures of smaller groups of industries, such as the utilities sector, it becomes more important to consider the effects of intermediate inputs. If intermediates were omitted, economies or diseconomies in their use would not be reflected correctly in the productivity measure.

Inclusion of intermediate inputs implies a broader definition of *output.* Now, gross output would equal all sales by public utilities, including those to other utilities. In this study, we develop measures of *sectoral output,* defined as sales to customers *outside* the public utilities sector.[6] Sectoral output differs from gross output in that it avoids double counting *intra*industry transactions. These transactions are important for electric and gas utilities because of the substantial amounts of gas and electricity resold among them and because of consumption of gas by electric utilities.

Intraindustry sales of gas and electricity are excluded from input as well as from output. With respect to the electric utilities, this helps to focus the analysis on efficiency in the conversion of fossil fuels to electricity and on the delivery of electricity to end users. In effect, those quantities of electricity transmitted between producers are removed from both output and energy input.

Identification of intraindustry gas sales is complicated by the fact that the gas industry is divided between two major SIC industry groups. Gas is produced at wells and processing plants classified in SIC 13, oil and gas extraction. It is then purchased by pipeline and distribution companies in SIC 49 and is transported, after possibly being stored for a time, and delivered to final consumers. Gas sold by producers in SIC 13 to pipelines and distributors in SIC 49 is classified as input in this study, but gas resold by pipelines to distributors is not. The latter transactions account for the bulk of intraindustry gas sales. Purchases from gas utilities by electric utilities are also excluded from energy input and from output.

Typically, utility companies are engaged in two major types of activities: delivery of utility services and construction of facilities. Construction work performed by utilities is considered an output of the *construction industry,* and not the utility services industry, because it is a fundamentally different type of production from the delivery of utility services.[7]

The measure of multifactor productivity in utility services industries introduced in this analysis is an index computed from annual rates of multifactor productivity growth. The multifactor productivity growth rate is computed as the rate of growth in sectoral output less the rate of growth in aggregate input; that is,

$$(1) \quad \Delta \ln A = \Delta \ln Y - \Delta \ln I,$$

where Δln refers to differences in successive logarithms, A is an index of multifactor productivity, Y is an index of sectoral output, and I is an index of aggregate input.

The measure I is computed as a Tornqvist index of the five major types of inputs as follows.[8] First, annual rates of growth in aggregate input are computed:

$$(2) \quad \Delta \ln I = \sum_i w_i \Delta \ln X_i.$$

Here, Δln refers to differences in successive logarithms, X_i are quantity indexes of inputs i $(i = K,L,E,M,S)$, and w_i are averages of the factor shares in income of each input (s_i) in the current and previous years; that is,

$$(3) \quad w_{i,t} = (s_{i,t} + s_{i,t-1})/2.$$

Then the aggregate input index (I) is constructed as a "chain index," that is to say, by setting I_0 equal to 1 in the first year and computing I_t for each successive year — 1 year at a time — using the time series of input growth rates ($\Delta \ln I_t$) and the formula

(4) $$I_t = I_{t-1} e^{\Delta \ln I_t}.$$

Similarly, the multifactor productivity index (A) is constructed from the multifactor productivity growth rates ($\Delta \ln A_t$) in formula (1):[9]

(5) $$A_t = A_{t-1} e^{\Delta \ln A_t}.$$

Data. Total input is a Tornqvist aggregate of quantity measures for each of the five major types of input. These major input measures are, in turn, Tornqvist indexes of more detailed input categories, as dictated by the availability of data. In general, we begin with quantity indexes for specific inputs at the most detailed level that source data permit. A price series corresponding to each input is calculated by dividing current dollar expenditures on the input by the quantity index. These data permit computation of Tornqvist chain indexes for each major type of input and, thus, for total input.

Total output is computed as a Tornqvist aggregate of quantity indexes for the output of each utility service.[10] In turn, output indexes for both electricity and natural gas services are derived from sales and revenue data for several categories of consumption.[11]

Ideally, source data express quantity in physical units and in sufficient detail that each category within output and input is homogeneous. This is approximately true for electricity and gas output and for capital and energy inputs. Data for electricity and gas output are reported by type of customer, distinguishing otherwise homogeneous products on the basis of their unit costs of production and delivery. Aggregate capital input is derived from data for 17 types of capital, and energy input is based on 10 different fuels. Physical quantities are also reported for gas used as a material input in production.

Data on expenditures must be relied upon in the development of both nongas materials and business services inputs. Several categories of purchases are deflated separately prior to aggregation, in an effort to obtain the most reliable constant-dollar measures possible.

Table 1. Compound annual rates of change in productivity and related measures for the utility services industries, 1948–88

Period	Multifactor and single-factor productivity					
	Multifactor productivity *QY/QI*	Capital *QY/QK*	Labor *QY/QL*	Energy *QY/QE*	Materials *QY/QM*	Business services *QY/QS*
1948–88	2.4	1.8	3.8	1.3	2.9	0.6
1948–73 (a)	3.6	3.4	6.2	1.2	3.6	.9
1973–88 (b)	.4	-.8	-.2	1.4	1.9	.1
Change (b – a)	-3.2	-4.2	-6.4	.2	-1.7	-.8
	Output and input					
	Output *QY*	Capital *QK*	Labor *QL*	Energy *QE*	Materials *QM*	Business services *QS*
1948–88	5.4	3.6	1.6	4.1	2.5	4.8
1948–73 (a)	7.8	4.3	1.5	6.5	4.1	6.9
1973–88 (b)	1.6	2.4	1.8	.2	-.3	1.5
Change (b – a)	-6.2	-1.9	.3	-6.3	-4.4	-5.4
	Prices					
	Output *PY*	Capitol *PK*	Labor *PL*	Energy *PE*	Materials *PM*	Business Services *PS*
1948–88	3.7	5.8	6.5	5.4	7.3	4.5
1948–73 (a)	.6	4.3	5.5	2.1	4.0	3.2
1973–88 (b)	9.2	8.5	8.1	11.0	13.1	6.8
Change (b – a)	8.6	4.2	2.6	8.9	9.1	3.6

NOTE: Q = quantity; P = price; Y = sectoral output; I = total inputs; K = capital input; L = labor input; E = energy input; M = materials input; S = purchased business services input.

Only labor input is based on one category of source data. It is measured in hours paid for, where hours of all employees are considered homogeneous. Hours of employees devoted solely to construction of new facilities are excluded. This is consistent with the definition of output as utility services provided to other sectors. Labor hours devoted to construction of facilities are an input to the construction industry. The facilities themselves are capital goods and are inputs to the utilities services industry.

Table 2. **Average factor shares in income in utility services industries, 1948–88**

Period	Total input	Capital	Labor	Energy	Materials	Business services
1948–88	1.00	0.45	0.18	0.14	0.15	0.08
1948–73 (a)	1.00	.49	.21	.10	.12	.08
1973–88 (b)	1.00	.38	.15	.21	.18	.08
Change (b – a)	.00	–.11	–.06	.11	.06	.00

Results

Measures of growth in multifactor productivity and in single-factor productivities for the utility services industries appear in table 1. Growth rates in quantities and prices of output and each of the five major inputs are also displayed. The growth rates are presented for 1948 to 1988, as well as for the pre-1973 and post-1973 periods, which, by convention, are compared in studies of the productivity slowdown.

Multifactor productivity in utility services industries grew at an average rate of 2.4 percent per year from 1948 to 1988, compared with 1.2 percent per year in the whole nonfarm business sector. The average rate spans periods of quite different performances in productivity by the utilities. A rate of growth of 3.6 percent per year during the 1948-73 period was followed by a 0.4-percent annual growth rate from 1973 to 1988. This slowdown of 3.2 percent per year reflects a dropoff of 6.2 percent per year in the growth rate of output, accompanied by a 2.9-percent decline in the annual rate of input growth. (See chart 1.)

The first absolute declines in utility services output in the postwar era occurred in 1974 and 1982. These years also witnessed falling output for the nonfarm business sector. The slower growth of utility services output after 1973 coincided with average increases in the price of utility services of 9.2 percent per year.

Total input growth is a weighted sum of changes in the quantities of individual inputs, with the weights being the shares in total income of each input. Table 1 shows rates of growth in the quantities of individual inputs, and table 2 shows the average share in income of each. In the post-1973 period, the only input whose quantity decreased was materials, while energy input grew very slowly. (See chart 2.) The use of purchased business services increased, but contributed little to growth in total input, due to business services' modest share in income. Capital input, with a 38-percent average cost share from 1973 to 1988, grew faster than output and accounted for two-thirds of total input growth after 1973. Labor input growth also added to growth in aggregate input.

Comparisons of changes in output relative to those in each input are expressed as single-factor productivity statistics in table 1. Although these statistics relate changes in output to changes in individual types of input, they do not measure the specific contribution of any single factor of production. Rather, they reflect the joint effects of many influences, including changes in technology, in levels of output, and in the organization of production.

Capital productivity growth slowed 4.2 percent per year from the pre-1973 period to the post-1973 period. While output growth fell by

Table 3. Percent of capacity utilization, utilities, 1967–88

Year	Percent
1967	93.4
1968	94.1
1969	95.8
1970	95.4
1971	93.9
1972	94.6
1973	92.9
1974	86.8
1975	83.9
1976	84.8
1977	84.6
1978	84.8
1979	85.9
1980	85.5
1981	82.8
1982	79.5
1983	80.3
1984	82.5
1985	83.5
1986	80.2
1987	82.5
1988	84.2
1967–73 average	94.1
1973–88 average	85.8

Chart 1. **Output, total input, and multifactor productivity in utility services industries, 1948-88**

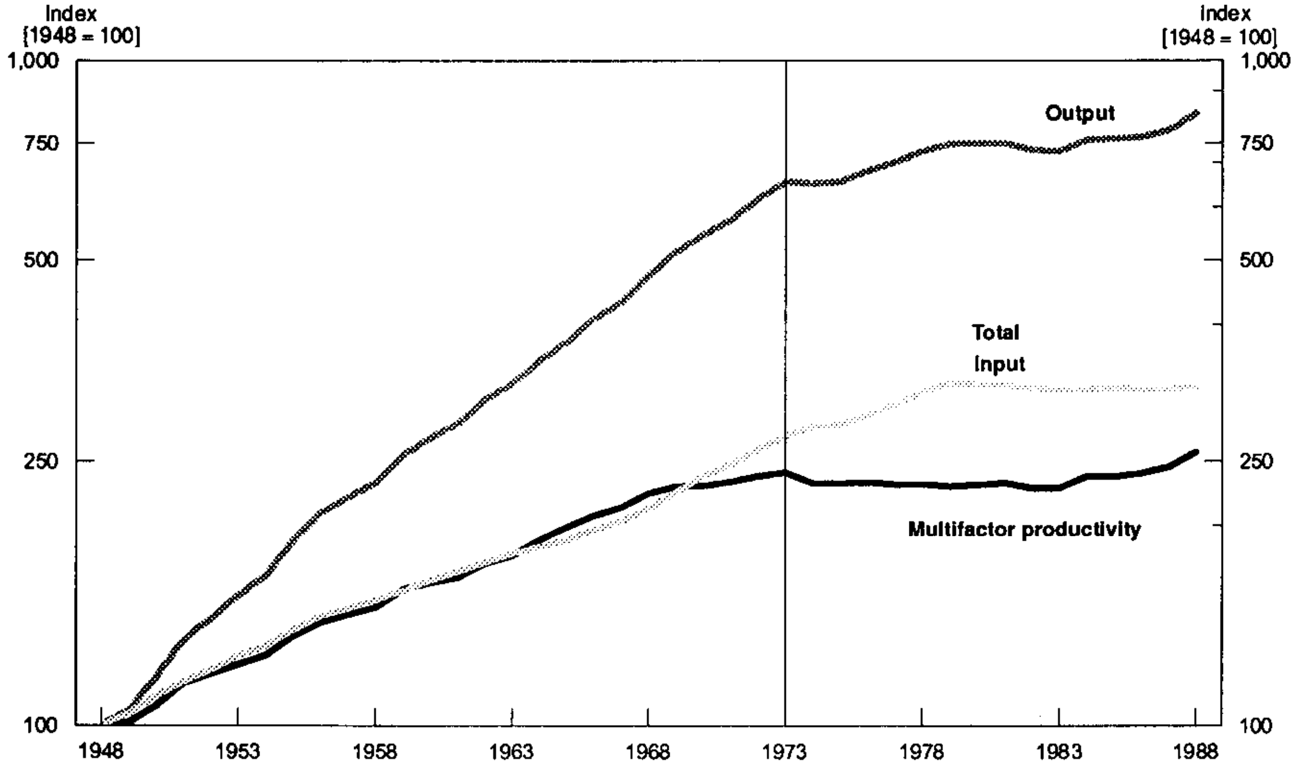
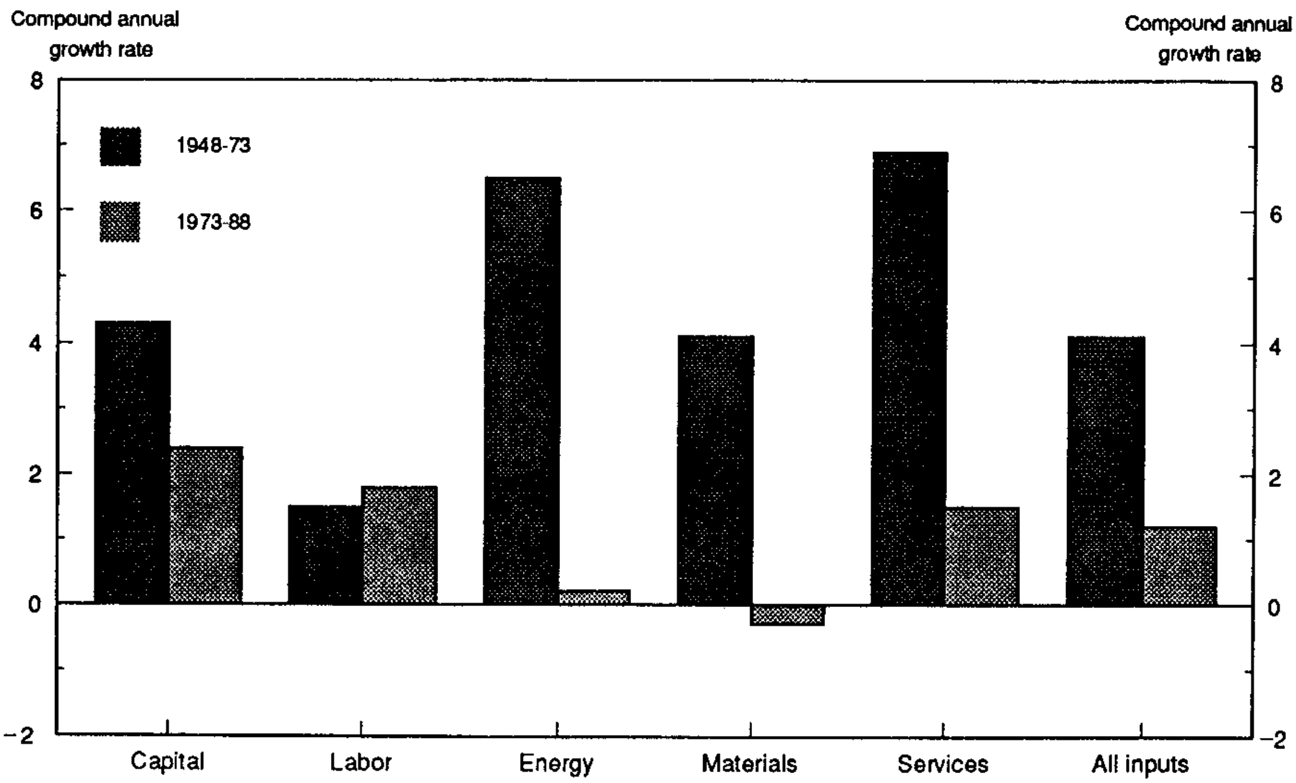


Chart 2. **Growth in input quantities before and after 1973**



6.2 percent annually, capital input growth fell by only 1.9 percent per year. This difference may be explained by the nature of capital investment in the public utilities industry. Capital stock is extremely inflexible for utilities. Investment in electricity-generating plants, gas pipelines, and sewer lines must begin years ahead of desired completion. Once built, these structures may last for several decades. When demand falls short of expectations, capital input is adjusted in the short run by decreasing the use of existing capital, rather than by reducing the level of capital stock or expenditures on future capital. For example, slow economic growth from 1973 to 1975 and from 1979 to 1983, combined with high electricity and gas prices, resulted in depressed demand for utility output after 1973. Meanwhile, investment initiated years earlier under conditions of growing demand came to fruition and expanded capacity. These two effects together resulted in excess capacity, as illustrated in table 3 (page 37).[12]

Excess capacity has important implications for the interpretation of the slowdown in capital productivity after 1973. When capacity is underutilized, the capital services input measure may overstate capital input.[13] Output per unit of capital would, in turn, be understated. If the capital input measure does not fully capture changing capacity utilization, then growth in capital services input declined more than 1.9 percent per year after 1973, and the post-1973 slowdown in capital productivity is exaggerated.

Labor productivity growth in utility services showed an even more pronounced drop than did multifactor productivity, from an increase of 6.2 percent per year before 1973 to a decline of 0.2 percent per year for the 1973-88 period, or a drop of 6.4 percent per year between the two periods. Changes in output per hour were similar to those in output, because the use of labor accelerated slightly after 1973, while the consumption of all other inputs slowed. However, it is important to remember that this dropoff in output per hour is indicative of substitution effects among all inputs, as well as other effects, and therefore does not attribute poor productivity performance solely to labor.

A relationship between measures of labor productivity and multifactor productivity can be derived from the formula (1) used to compute multifactor productivity growth.[14] Changes in labor productivity may be expressed as the combination of multifactor productivity growth and changes in the ratio of each nonlabor input to labor. In table 4, the post-1973 slowdown in labor productivity growth is explained in terms of multifactor productivity growth and contributions of factor intensities.[15] During the 1948-73 period, all of the nonlabor inputs grew relative to labor and thus enhanced labor productivity growth. However, multifactor productivity growth of 3.6 percent per year outweighed all of these factor intensity effects (2.6 percent per year combined). By the same token, half of the dropoff of 6.4 percent per year in output per hour growth after 1973 is attributed to the slowdown in multifactor productivity. The falling rate of growth in the capital-to-labor ratio was associated with 1.1 percent per year of the decrease in output per hour growth. And declines in the ratios of both energy and materials to labor contributed another quarter of the slowdown in labor productivity growth.

Table 4. **Portions of labor productivity growth attributable to multifactor productivity growth and shifts in factor intensity, 1948–88**

(Percent changes at compound annual rates)

Period	Output per hour	Contributions from— Multifactor Productivity	QK/L	QE/L	QM/L	QS/L
1948–88	3.8	2.4	0.9	0.2	0.0	0.2
1948–73 (a)	6.2	3.6	1.4	.5	.3	.4
1973–88 (b)	–.2	.4	.3	–.4	–.5	.0
Change (b – a)	–6.4	–3.2	–1.1	–.9	–.8	–.4

NOTE: Q = quantity; K = capital input; L = labor input; E = energy input; M = materials input; S = purchased business services input.

Table 1 shows that energy productivity growth accelerated 0.2 percent per year after 1973, while all other single-factor productivity growth rates decreased. (See chart 3.) This may have been due to the rapid increase in the price of fossil fuels, which provided an incentive to economize in their use. From 1973 to 1988, the price of energy inputs increased 11.0 percent per year, and the consumption of energy inputs by utilities slowed more after 1973 than that of any other input. (See chart 2.) The cost share of energy input doubled, despite the slowdown in energy consumption of 6.3 percent per year after 1973.

Growth in output per unit of materials input fell from 3.6 percent per year for the 1948-73 period to 1.9 percent per year during 1973-88, but this figure was still the highest productivity growth rate of any input in the post-1973 period. Materials prices increased 13.1 percent annually after 1973, due primarily to the price of natural gas, which accounts for two-thirds of materials input purchases. (See chart 4.) The large increase in materials prices led to a rise in the cost share of materials, from 12 percent

Chart 3. Growth in single-factor productivities and multifactor productivity before and after 1973

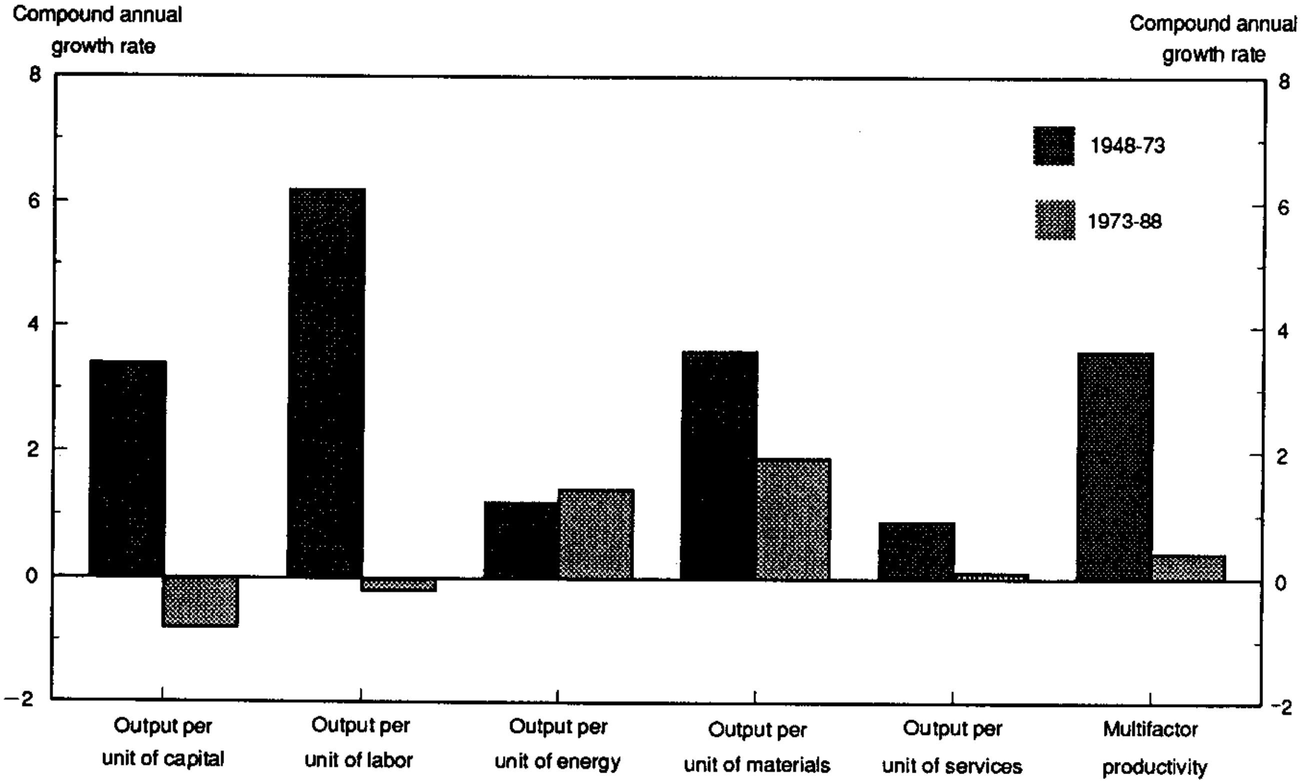
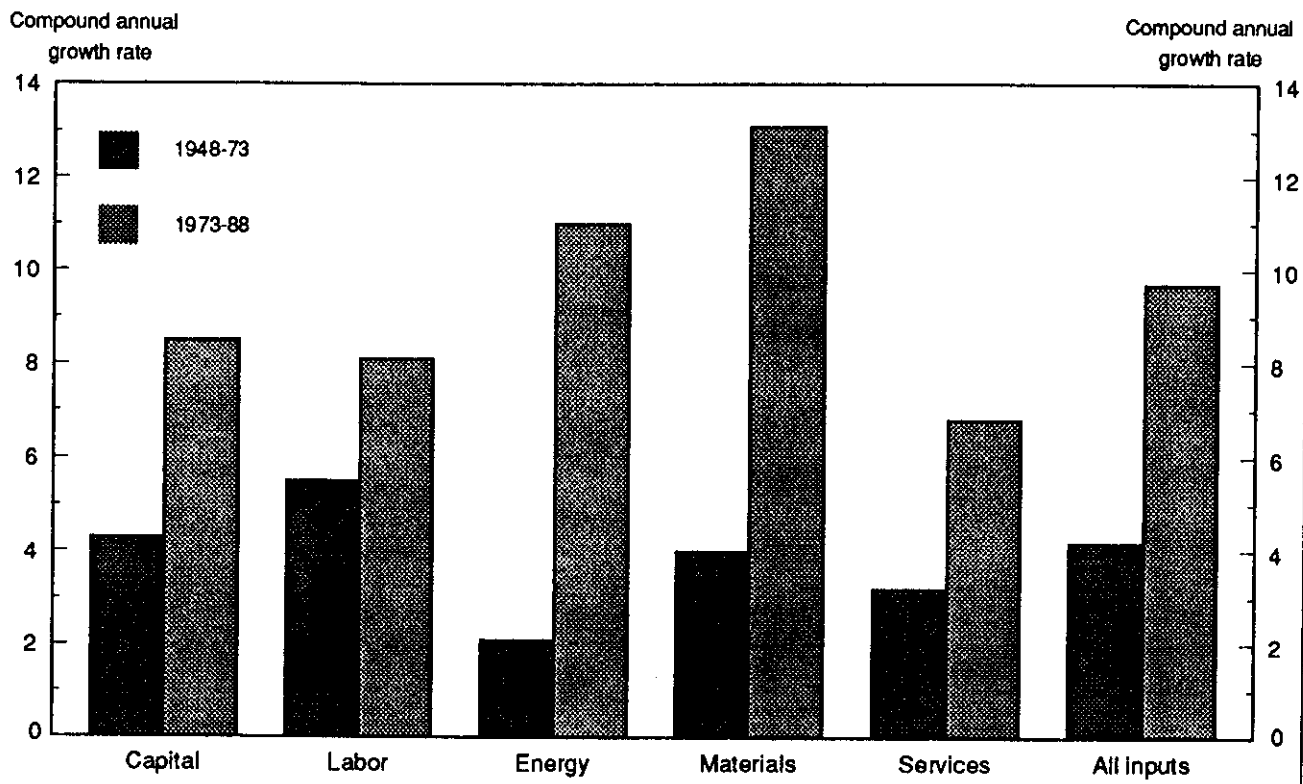


Chart 4. Growth in input prices before and after 1973



during 1948-73 to 18 percent for the 1973-88 period, even though the annual growth rate of materials use fell 4.4 percent after 1973, to -0.3 percent per year.

Of all single-factor inputs, business services showed the least improvement in productivity over the study period, 0.6 percent per year. Average increases of 0.9 percent annually from 1948 to 1973 were not sustained after 1973, when the growth rate fell to an average of 0.1 percent per year. (See chart 3.) Because the share of services in total factor cost was only 8 percent, this backslide did not contribute significantly to the slowdown in multifactor productivity.

Summary and conclusions

The BLS project presented in this article developed indexes of total output and five major inputs for utility services industries, which are used to compute an index of multifactor productivity. The annual rate of change in the multifactor productivity index for the 1948-88 period was 2.4 percent per year. Results for the periods before and after 1973 are also reported and reveal a multifactor productivity slowdown of 3.2 percent per year. Single-factor productivity statistics show large slowdowns in both labor and capital productivity for public utilities. Energy productivity grew an average 1.3 percent per year throughout the 1948-88 period and was unique in its improvement from the pre-1973 to the post-1973 period. Although materials productivity growth slowed after 1973, at 1.9 percent per year it exceeded all other single-factor productivities during the post-1973 period.

Rates of growth in the quantities and prices of inputs and output are presented and provide insight into the continued growth in energy and materials productivity. Energy consumption grew 6.5 percent per year, on average, from 1948 to 1973 and then leveled off. Materials input use increased 4.1 percent annually during the same period, but declined 0.3 percent per year thereafter. Meanwhile, consumption of all other inputs continued to grow in the post-1973 period, which suggests that other inputs were substituted for energy and materials after 1973. This is not surprising, given the growth in the prices of those two inputs: 11.0 percent per year for energy and 13.1 percent per year for materials during 1973-88.

Analysis of the two components of materials input revealed that output per unit of nongas materials fell off dramatically after 1973, while productivity of natural gas used as a material input improved.[16] Natural gas accounts for about two-thirds of materials expense, so increasing fossil fuel prices after 1973 may have had a positive impact on the efficiency with which natural gas is transported, similar to the improvement in energy productivity, representing fossil fuels that are burned.

Capital is found to account for a much larger share in total factor income than any other input, so that changes in capital input have a bigger impact on multifactor productivity than do proportionate changes in the other inputs. Therefore, the modest 2.4-percent rate of growth in capital input from 1973 to 1988 was a major cause of the productivity slowdown, compared with the 1.6-percent growth achieved in output.

The precipitous fall in labor productivity growth of 6.4 percent per year from the pre-1973 period to the post-1973 period can be mathematically attributed to changes in other factors with respect to labor and to changes in multifactor productivity. The slowdown in output per hour coincided with slower growth in the capital-to-labor ratio and with absolute declines in the intensity of energy and materials inputs relative to labor. Half of the labor productivity slowdown is associated with declining multifactor productivity growth.

The measure of multifactor productivity presented in this article describes the relationship between real output and five major inputs involved in its production. Changes in this relationship, and thus in multifactor productivity, reflect the joint effects of many influences, including new technology, economies of scale, and changes in the efforts and characteristics of the work force. These effects are not measured separately here, but previous studies suggest that economies of scale are responsible for some of the increases in multifactor productivity in the electric utility industry.

Laurits Christensen and William Greene analyzed firm-level data for private electric utilities for the years 1955 and 1970.[17] Focusing only on generation of electricity, they found that "in 1955 there were significant scale economies available to nearly all firms. By 1970, however, a large share of total electric power was generated by firms which had exhausted scale economies."[18] Frank Gollop and Mark Roberts examined all operations of a subset of these same private electric utilities for the period 1958 to 1975 and concluded that there were scale economies available throughout their sample.[19] They pointed out that this is not inconsistent with the findings of Christensen and Greene, because, "while economies in generation may well be exhausted at a relatively small scale of operation, engineering considerations suggest that significant economies persist in both transmission and distribution."[20]

It is likely that scale economies are also associated with the transmission and distribution of natural gas. The fact that the price of natural gas for industrial use is much less than that for commercial or residential use implies that distribution costs decrease as consumption per customer increases. Historically, quantities of gas used by customers within each consumer category have increased, reducing distribution costs for the same reasons that industrial service costs less than residential service at a given point in time. Serving growing numbers of customers may also provide opportunities to exploit scale economies.

Economies of scale have probably been realized by the utility services industries during part or all of the 1948-88 period. However, the framework within which multifactor productivity is measured in this article assumes *constant* returns to scale. Because of this assumption, multifactor productivity measures reflect scale effects, along with other sources of productivity growth. If, as some empirical evidence suggests, multifactor productivity benefited more from scale economies in the pre-1973 period than in the post-1973 period, this would explain part of the slowdown in its rate of growth.[21] □

Footnotes

[1] The utility services industries are classified in Standard Industrial Classification (SIC) major industry group 49 and are engaged in the generation, transmission, and distribution of electricity; transmission and distribution (but not production) of natural gas; distribution of water; and collection and disposal of waste. Government-owned utilities are excluded from the new measure to maintain consistency with the BLS measure of multifactor productivity for the private business sector. See Executive Office of the President, Office of Management and Budget, *Standard Industrial Classification Manual* (Washington, U.S. Government Printing Office, 1987), p. 237.

[2] Indexes of output per hour and related measures for gas and electric utilities (SIC's 491, 492, and 493) appear in *Productivity Measures for Selected Industries and Government Services*, Bulletin 2406 (Bureau of Labor Statistics, April 1992).

[3] This figure is the change in the rate of growth in output per hour worked from the 1948-73 period (2.5 percent per year) to the 1973-88 period (0.8 percent per year).

[4] *Annual Energy Review, 1990* (Department of Energy, May 1991), Table 4, pp. 11-12. Data reflect the entire electric utility industry.

[5] A BLS measure of multifactor productivity in the railroad transportation industry, also in the services sector, appears in *Productivity Measures for Selected Industries and Government Services*.

[6] This definition of outputs and inputs in terms of transactions outside the sector will ultimately allow comparisons of productivity measures for different levels of aggregation, using a method proposed in E. D. Domar, "On the Measurement of Technical Change," *Economic Journal*, Vol. LXXI (December 1961), pp. 709-29. The definitions are consistent with the study of multifactor productivity in two-digit SIC manufacturing industries by William Gullickson and Michael Harper, "Multifactor productivity in U.S. manufacturing, 1949-83," *Monthly Labor Review*, October 1987, pp. 18-28.

[7] This is the way construction is handled by the Bureau of Economic Analysis of the Department of Commerce in its input-output analysis.

[8] A Tornqvist index is a discrete approximation to a Divisia index. W. E. Diewert has demonstrated ("Exact and Superlative Index Numbers," *Journal of Econometrics*, Vol. 4, No. 4, 1976, pp. 115-45) that the Tornqvist index is a "superlative index number formula," which means that it gives an accurate aggregate under fairly general conditions. According to Diewert, the Tornqvist index is "exact" for a translogarithmic production function. In that case, sectoral output (Y) is produced at time t using inputs of capital (K), labor (L), energy (E), materials (M), and purchased business services (S); that is,

$$Y = f(K,L,E,M,S,t).$$

For further discussion of the multifactor productivity model, see *Trends in Multifactor Productivity, 1948-81*, Bulletin 2178 (Bureau of Labor Statistics, September 1983), pp. 33-34.

[9] The multifactor productivity index may also be computed as the ratio of the index of sectoral output to the index of aggregate input, or Y/I.

[10] The use of Tornqvist aggregation of outputs is consistent with a model of joint production in which "representative firms" choose how much of each output to produce based on maximization of profit, given exogenous output prices and a "transformation function." The properties of transformation functions are analyzed in W.E. Diewert, "Functional Forms for Profit and Transformation Functions," *Journal of Economic Theory*, 1973, Vol. 6, pp. 284-316.

[11] Output of water companies and companies offering other sanitary services is based on receipts data, which do not involve Tornqvist aggregation.

[12] See Federal Reserve System, Division of Research and Statistics, *Capacity Utilization, Manufacturing, Mining, and Utilities and Industrial Materials, January 1967-December 1984* (Washington, Board of Governors of the Federal Reserve System, July 1985); and *Industrial Production and Capacity Utilization* (Washington, Board of Governors of the Federal Reserve System, monthly press releases, June 1985-May 1989).

[13] The capital input measure used here is a weighted aggregate of capital assets, where the weights are implicit rental prices of these assets. In the traditional framework for the measurement of multifactor productivity, capital inputs are assumed to be fully utilized, allowing capital stocks to be used as proxies for the flow of capital services. When the assumption of full capacity utilization does not hold, capital stock may no longer be a valid proxy for capital services. Two studies addressing this issue are Ernst Berndt and Melvyn Fuss, "Productivity Measurement with Adjustments for Variations in Capacity Utilization and Other Forms of Temporary Equilibrium," and Charles Hulten, "Productivity Change, Capacity Utilization, and the Sources of Efficiency Growth," both of which

appeared in the *Journal of Econometrics*, Vol. 33, Oct.-Nov. 1986. These analyses show that variations in capacity utilization are captured in multifactor productivity measures through the use of an ex post rental price in the weight on capital input. The ex post rental price of capital would decrease when capacity was underutilized, and, compared with the traditional measure, multifactor productivity growth would be increased. Since the Bureau uses an ex post procedure in computing the rental price of capital, the effect of variations in capacity utilization on the capital or multifactor productivity measures may, to some extent, already have been captured. For further discussion, see Susan Powers, *Cyclical Movements in BLS Multifactor Productivity Measures and Capacity Utilization*, Working Paper 198 (Bureau of Labor Statistics, August 1989).

[14] Starting with

$$\Delta \ln A = \Delta \ln Y - w_K \Delta \ln K - w_L \Delta \ln L - w_E \Delta \ln E - w_M \Delta \ln M - w_S \Delta \ln S,$$

to both sides we add $\Delta \ln Y$, subtract $\Delta \ln A$, and multiply by −1 to obtain

$$\Delta \ln Y = \Delta \ln A + w_K \Delta \ln K + w_L \Delta \ln L + w_E \Delta \ln E + w_M \Delta \ln M + w_S \Delta \ln S.$$

Subtracting $\Delta \ln L$ (in the form $(w_K + w_L + w_E + w_M + w_S) \Delta \ln L$, with $(w_K + w_l + w_E + w_M + w_S)$ equal to 1 on the right side) yields

$$\Delta \ln Y - \Delta \ln L = \Delta \ln A + w_K \Delta \ln K + w_L \Delta \ln L + w_E \Delta \ln E + w_M \Delta \ln M + w_S \Delta \ln S - (w_K + w_L + w_E + w_M + w_S) \Delta \ln L,$$

or

$$\Delta \ln Y - \Delta \ln L = \Delta \ln A + w_K (\Delta \ln K - \Delta \ln L) + w_E (\Delta \ln E - \Delta \ln L) + w_M (\Delta \ln M - \Delta \ln L) + w_S (\Delta \ln S - \Delta \ln L),$$

where the left side is equivalent to labor productivity growth and the terms on the right side represent multifactor productivity growth and changes in the ratios of each nonlabor factor to labor multiplied by that factor's average share in income.

[15] The contributon of a factor's intensity to growth in output per hour is defined as the factor's cost share times the growth rate of the ratio of the factor's quantity to labor hours. This is not a causal explanation of growth in output per hour, as noted by Michael Harper and William Gullickson in "Cost Function Models and Accounting for Growth in U.S. Manufacturing, 1949-86," presented at the National Bureau of Economic Research Summer Institute, July 24-28, 1989.

[16] The rate of growth in productivity of natural gas used as a material increased from 2.0 percent per year in the 1948-73 period to 4.8 percent per year during 1973-88. Productivity growth of other materials fell from 5.0 percent per year prior to 1973 to −3.0 percent per year in the post-1973 period.

[17] Laurits Christensen and William Greene, "Economies of Scale in U.S. Electric Power Generation," *Journal of Political Economy*, Vol. 84 (August 1976), pp. 655-76.

[18] Christensen and Greene, "Economies of Scale," p. 656.

[19] Frank Gollop and Mark Roberts, "The Sources of Economic Growth in the U.S. Electric Power Industry," in Thomas Cowing and Rodney Stevenson, eds., *Productivity Measurement in Regulated Industries* (New York, Academic Press, 1981), pp. 107-43.

[20] Gollop and Roberts, "Sources of Economic Growth," p. 127 (footnote 23).

[21] Gollop and Roberts, *ibid.*, p. 140, estimated that, for selected electric utilities, the average annual change in productivity growth due to scale economies was 1.8 percent from 1958 to 1973 and −0.1 percent during the 1973-75 period.

APPENDIX: Data sources and methods

Following are discussions of the data and methods used to develop indexes of each major input and each type of output. In some instances, data for more than one three-digit industry must be processed together, and the methodology is presented jointly.[1] For example, the best available data on electricity sales include sales of electricity by combination electric and gas companies. Similarly, sales of gas by combination utilities are included in the data on gas sales. Thus, measures developed separately for electric utilities and gas utilities, when summed, encompass SIC industries 491 through 493. In general, no problem is presented by source data that overlap three-digit industries, because such data are aggregated to the two-digit level.

Output measures

In 1988, the value of sectoral output for privately owned utilities was approximately $200 billion. Seventy percent ($140 billion) was accounted for by electricity services, 20 percent ($40 billion) by gas services, and 10 percent ($20 billion) by all other utility services combined.

Electric services. Electricity output is measured in kilowatthours. Because the utilities are engaged in distribution as well as generation of electricity, output is based on kilowatthours sold to ultimate consumers, not kilowatthours generated. Although electricity would seem to be homogeneous, consideration of the distributive service reveals differences in the product provided to various types of customers. In many cases, industrial customers receive larger amounts of electricity at higher voltage, and therefore lower unit cost, than do residential customers; the unit cost of distribution is inversely related to the quantity supplied. For this reason, most electric utilities employ a rate structure distinguishing several classes of service. In the aggregation of electric services output, kilowatthours sold to each class of service are weighted by the price of that service, in order to value the several types of output according to their relative unit costs.

The cost of generating electricity at a given plant varies with the time of day and season of the year. It is generally higher during a peak load period, primarily because equipment that is less efficient due to age or because it requires a more expensive type of fuel may be called into service. Industrial customers are sometimes able to pay lower rates by scheduling work to take advantage of offpeak prices, but residential customers are not generally offered this option and, in any event, cannot schedule consumption to take advantage of such discounts. This source of disparity between the average prices paid by residential and industrial customers is also reflected in the output series, via smaller price weights applied to industrial consumption. Similarly, lower rates resulting from long-term contracts are captured in the output measure.[2]

The price-weighted electric services output measure reflects variable distribution costs, as well as rate differences among classes of service that are related to the cost of generation of electricity. The measure prevents bias in productivity measures due to changes in the distribution of sales among classes of service. For example, if output were defined as unweighted kilowatthour sales, productivity gains would be inferred incorrectly if consumption shifted toward the low-cost industrial service.[3]

The development of output is made possible by excellent source data. The Energy Information Administration of the Department of Energy publishes electricity sales and revenues by class of service for "selected investor-owned electric utilities."[4] These data cover practically all of the privately owned electric utility industry, with which we are concerned. Cooperatively owned electricity production is reported by the Department of Agriculture's Rural Electrification Administration and is used to supplement the Department of Energy data.[5]

Purchases of electricity by Federal and municipal electric utilities from private electric utilities should be included in output. However, these transactions are excluded therefrom in this study, along with sales between private electric utilities, because sales for resale are reported in total by the Department of Energy. Related published data indicate that in 1985, these sales were at most 6.4 million megawatthours of the 337.1 million megawatthours sold for resale by private utilities.

Gas production and distribution. By definition, gas utility services include the transmission, storage, and distribution of all gas, as well as the production of manufactured, mixed, and liquefied petroleum gas.[6] As a statistical matter, gas services output is approximated by gas sales to ultimate consumers. Natural gas sales currently account for 99 percent of all gas sales to final consumers and are therefore virtually equal to output. During 1947, the figure was 87 percent, with manufactured gas accounting for 8 percent and mixed gas for 5 percent of sales. However, by 1955, manufactured gas production was less than 1 percent of output, and the share of natural gas had climbed to 95 percent. The remainder was mixed gas, production of which plummeted shortly thereafter. Liquefied petroleum gas has never been important statistically in aggregate industry data.

It is the distributive aspect of gas service that gives rise to the large differences in rates facing various categories of customers; gas utilities have not produced substantial amounts of gas for decades. As in the case of electric utility service, the quantity of sales in each category is weighted by its revenues, yielding an index of output that recognizes the different costs of distribution. Sales and revenue data for residential, commercial, industrial, and other customers for the period 1947-89 are available through the American Gas Association.[7]

Because the gas output series is but a constituent of a sectoral output series for all utility services, sales of gas to electric utilities must be removed from output. Sales of gas for the generation of electricity, together with corresponding revenues, are included in the "industrial" and "other" categories of the American Gas Association data. They are also reported separately and so may be deducted from these categories of sales and revenues prior to aggregation of output. Analogously to the case of electricity output, purchases of gas by publicly owned electric utilities should be included in output, but are removed along with the much larger amounts of gas sold to privately owned electric utilities.

Gas sold by municipally owned gas companies is included in the source data and must also be removed from output to be consistent with the restriction of this measure to privately owned utilities. Data on recent sales and revenues are reported by type of ownership in *Gas Facts*, and additional data are available from the American Gas Association. Data on municipal gas sales have been provided for 1974 through 1989 and corresponding revenues from 1980 forward. Prior to 1974, municipal gas sales could be derived by deducting sales by private gas companies from sales by all gas companies. Moreover, the details by class of customer during 1974-84 revealed that the distribution of total municipal gas sales among the four service classes was nearly constant over the period. The total municipal sales in each year from 1948 to 1973 were distributed on the basis of the average percent distribution from 1974 to 1984. Finally, sales by class of service were multiplied by the average price of all gas sales by class, and both sales and revenues of the municipal gas companies were subtracted from output.

Ideally, electricity and gas sales to privately owned companies dealing in water and sanitary services would be excluded from the output measure. Data for private companies are not reported separately from sales to publicly owned firms, which account for a large majority of such transactions.[8] Electricity and gas consumed by private water and sanitary services companies is not deducted, but the overstatement of output is insignificant. For example, the *total* water and sanitary services industry consumption of electricity and gas of $12.7 million in 1972 was just 0.03 percent of the $37.446 billion in sectoral output of the private utilities services industry.[9]

Water supply and sanitary services. The Internal Revenue Service publishes estimated business receipts by corporations for water, sanitary services, steam, and irrigation services (SIC industries 494 through 497).[10] Actually, data for 1947 through

1957 cover water services only, but all of the preceding are reflected in data from 1958 to 1988. The data are based on income tax returns of a sample of corporations that changes from year to year. Similar treatment is given to returns by partnerships and sole proprietors, but the results are not reported separately for water and sanitary services. These current-dollar receipts data are deflated using the implicit price deflator for private consumption of water and sanitary services developed by the Bureau of Economic Analysis.[11] The constant-dollar revenue series is then indexed and used to complete the aggregation of total utility services output. The Internal Revenue Service data do not permit subtraction of intraindustry consumption of water and other sanitary services. However, in 1972, electric and gas utilities purchased less than 1 percent of water and other sanitary services output.[12]

Input measures

Capital input. Capital input is defined as the flow of services from the capital stock and is assumed to be proportional to that stock. Utility industry capital stock includes equipment, structures, and land. Data on investment in these capital assets are published by the Bureau of Economic Analysis for several two-digit SIC industries, including SIC 49.[13] The Bureau of Labor Statistics has developed capital stock measures for the depreciable assets (equipment and structures) of these industries by applying the perpetual inventory method to the Bureau of Economic Analysis investment data. This method involves the assumption that the efficiency of assets deteriorates with age. In particular, it is assumed that efficiency declines slowly in the early years of an asset's life and more rapidly later on. Inventories are based on estimates from the Bureau of Economic Analysis. Land is estimated as described in an unpublished BLS manuscript.[14]

Source data for 17 distinct types of capital assets contribute to the capital stock measure for SIC 49. Stocks of the several assets are combined using weights derived from estimates of implicit rental prices—the prices that the various types of capital would bring on a hypothetical rental market. These rental price estimates are calculated as the rate of return on the assets, plus the rate of depreciation, minus capital gains, all in nominal terms. Tornqvist aggregation over the individual assets yields a quantity index and price series for real capital input that may be used in the multifactor framework.[15]

Labor input. The unit of measure of labor input is the paid hour. In this study, no attempt is made to adjust for changes in labor composition. The scope of labor input is limited to operations and maintenance workers, with the intention of excluding any labor devoted to new construction. This is consistent with the definition of output as sales by utilities, rather than a broader concept that includes structures completed or in progress. Studies of multifactor productivity growth are thereby confined to the primary function of utilities, namely, the provision of electric, gas, water, or other services. This is a significant matter in the electric utility industry, because a quarter of its employees are construction workers. Thus, a desirable characteristic for source data for labor input is that such data distinguish these workers from the rest.

Sources of employment data for electric utilities are the statistical yearbooks of Edison Electric Institute and the Rural Electrification Administration.[16] The Edison Electric yearbook breaks out employment data into operations, maintenance, and construction workers and covers 98 percent of private industry. Edison Electric employment data extend back to 1951, and percent changes in employment in SIC 491, available from the BLS establishment survey, were used to move the Edison Electric series from 1951 back to 1947.[17] The Rural Electrification Administration reports only full-time employment, and this series is added directly to the Edison Electric series. Thus, it is assumed that no full-time construction workers are employed by Rural Electrification Administration borrowers.

The source data for employment in the gas utility industry are not well suited to distinguishing construction workers. Employment at private gas utilities is reported in *Gas Facts,* beginning in 1972. Construction workers are included in the total, but are not reported separately. It was possible to extend this series back to 1947 using employment in the total gas industry, which is reported for the entire study period by the American Gas Association. This left the matter of estimating and subtracting out construction labor. The American Gas Association reports payroll data broken out into operations, construction, and miscellaneous categories, starting with 1971 for the investor-owned part of the industry and with 1947 at the total industry level.[18] By assuming that wages of gas utility construction workers are competitive with those of the contract construction workers in SIC 162, which includes the building of gas pipelines, an estimate of employment in the private gas utility construction industry was derived back to 1972, the first year for which average weekly earnings for SIC 162 are reported by the Bureau of Labor Statistics in *Employment, Hours, and Earnings.* Subtraction of this series from the total employment series yields estimated nonconstruction employment for 1972-89. An alternative estimate of nonconstruction employment was then calculated under the assumption that construction workers in gas utilities earn the average wage for the gas utilities industry. In this manner, total employment could be distributed between the construction and nonconstruction parts of the industry in the same proportion as payroll in the industry is distributed. The method produced a series that moves in the same direction as the first estimated nonconstruction employment series in every year. We used movements in the latter series to complete the measure of nonconstruction employment in investor-owned gas utilities because that series covers a longer period than the other does.[19]

Employment in the other utility services, encompassing SIC industries 494 through 497, was found as the residual of employment in SIC 49 less employment in SIC industries 491 through 493. All of the required data appear in *Employment, Hours, and Earnings*, except for employment in SIC 492 and SIC 493 during 1947-49.[20] Stable employment trends during the early 1950's were utilized to estimate employment figures for the years 1947-49.[21] In the absence of evidence of construction labor in SIC's 494 through 497, it has been assumed that there is none there. Employment in SIC industries 494 through 497 is very small relative to that in electric and gas utilities (about 10 percent, on average, of the total for SIC 49), so that a fairly stable proportion of employees devoted to construction would not significantly affect the two-digit labor input trend.

Employment must be multiplied by average weekly hours and 52 weeks per year to find hours, the unit of measure of labor input. *Employment, Hours, and Earnings* also contains the data on average weekly hours used in this article.[22] Average weekly hours of nonsupervisory workers are reported by three-digit SIC industry, with data beginning in 1947 for SIC 491 and in 1950 for SIC 492 and SIC 493. These three industries combined cover all the private electric and gas utilities. Because the employment data for electric and gas utilities were developed separately, and because SIC 492 includes both electric and gas utilities, average weekly hours could not be applied at the three-digit level. Therefore, an average weekly hours series for SIC industries 491 through 493 combined was derived.

Average weekly hours for SIC 491 through SIC 493 combined were found by first multiplying average weekly hours by employment in each industry, where these data refer to nonsupervisory workers. Then the results were summed over the three industries. The sum was subsequently divided by the sum of nonsupervisory employment to get an average weekly hours figure for electric and gas utilities together. It was necessary to assume that average weekly hours in SIC 492 and SIC 493 were the same in 1947-49 as they were in 1950. Hours in electric and gas utilities are, then, the product of their summed employment, this combined average weekly hours series, and 52 weeks per year.

Hours for the remaining industries in SIC 49 were found as the residual of total employee hours in SIC 49 less total employee hours in SIC 491 through SIC 493. It was necessary to estimate average weekly hours in SIC 49 for the 1947-57 period using forecasting methods and data at the three-digit level.[23] The hours series thus obtained for SIC 494 through SIC 497 is based entirely on published data. Unpublished BLS data also permit direct calculation of hours for SIC industries 494 through 497 back to 1972. Differences between the two alternative series since 1972 are very small. Since the series estimated using published data would have to be used for years prior to 1972 in any case, it is used for the entire 1947-89 period. This series was then added to the nonconstruction worker hours series for SIC 491 through SIC 493 to complete the labor input series.

Weights for the labor input series are based on current-dollar payments to labor. The Bureau of Economic Analysis provides labor compensation data by two-digit industry wherein both wages and supplements to wages contribute to total compensation.[24] Total labor compensation is appropriate for use in the multifactor productivity framework, to account for all costs of production. After the labor input series is indexed, compensation in current dollars is divided by the index to get the corresponding series of prices.

Energy input. Electric utilities accounted for 85 percent of expenditures on energy input by SIC industry group 49 in 1960, 90 percent in 1970, and 92 percent in 1980. Energy input to electric utilities consists primarily of fossil fuels burned to drive electricity-generating plants. Electric utilities also produce electricity from water and wind and from solar and geothermal power. Accordingly, these are energy inputs, too. On the other hand, electricity is produced using nuclear fuel, yet nuclear fuel is included in capital input. The reason is that the long useful life of this energy source, about 5 years, suggests treating it as a depreciable capital asset.

The fossil fuels used to generate electricity are coal, oil, and gas. The treatment of coal and oil input is straightforward: the quantities consumed and prices paid for these two fuels by the electric utilities are incorporated into aggregate energy input. Technically, gas purchases by electric utilities from gas pipeline companies and gas distributors are excluded from energy input because these are *intra*industry transactions. However, these amounts of gas are properly included in energy input as *inter*industry sales from SIC 13 to SIC 49. Therefore, the quantity of gas consumed by electric utilities is included in energy input, but valued at the price paid to the gas producers in SIC industry 13.

The Energy Information Administration of the Department of Energy is able to provide data on quantities of coal, oil, and natural gas consumed by privately owned electric utilities from 1970 on.[25] These three series were extended back to 1947, based on closely related information available in the Edison Electric Institute statistical yearbook.[26] There, one finds data on the consumption of fossil fuels by all electric utilities for the entire period of the study. Quantities of electricity generated, by type of ownership and by type of prime mover driving the generator, are also reported back to 1947. This article uses electricity generation driven by conventional (as opposed to nuclear) steam engines and turbines and by internal combustion engines, because these are the prime movers that consume fossil fuels. The data were utilized as follows: the ratio of fossil fuel-powered generation at private electric utilities to that at all electric utilities was multiplied by the consumption of each fossil fuel by all electric utilities, giving estimated private fuel consumption. Estimated values for 1970-88 were compared with actual fuel consumption data provided by the Energy Information Administration, and the ratio of actual to estimated consumption of each fuel in 1970 was used to scale the estimated series prior to 1970.

Current-dollar costs are calculated for coal and oil as the product of consumption and average prices paid by electric utilities. The quantities of gas used are valued at the price originally paid to the producers of the gas by the pipeline companies. This price is available from 1958 on, and before that, the price of all marketed production serves as a good proxy. Price data are published in *Monthly Energy Review* by the Department of Energy.[27]

Natural gas that is transported through gas pipelines and utilities to final consumers outside SIC 49 is included in materials input, not energy input. But the smaller amounts used by the utilities themselves are energy input. Natural gas used for the purpose of generating electricity is discussed above. Gas is also used by gas utilities in the operation of pipelines, primarily for compressors, and must be included in fuel input. *Natural Gas Annual* reports the amounts of gas used for this purpose from 1947 on and corresponding prices from 1967 on.[28] Here again, the price of marketed production is used from 1947 to 1957. The price of pipeline fuel from 1958 to 1966 is reported in the *National Energy Accounts Data Base*, available from the Department of Commerce.[29] This is also the source of data on prices and quantities for other fossil fuel consumption by electric and gas utilities, such as gasoline for cars and trucks, and for water and geothermal power used by electric utilities.[30]

Energy input for the remaining utility services industries is provided in the *National Energy Accounts Data Base*.[31] The data are organized primarily by Bureau of Economic Analysis input-output industry, but a single industry classification—water supply and sanitary services—corresponds to SIC industries 494 through 497. The substantial detail describes how each of several types of fuel was used; the quantities used, in physical units; and the cost, in both current and constant dollars. Eight different petroleum products are Tornqvist aggregated to get the fuel input to SIC industries 494 through 497.

However, the *National Energy Accounts Data Base* reflects energy consumption by both private and government water and sanitary services providers, the majority being government. It is therefore necessary to adjust this component of energy input. The ratio of employment by private water and sanitary services companies to employment at all water and sanitary services companies is taken as an indicator of the portion of energy consumption attributable to the private firms. The development of data on private employment based on published BLS data has been described previously. Data on government employment in water and sanitary services are available from the Bureau of the Census.[32] The ratio of private to total employment increases throughout the 1958-88 period, from 11 percent to 26 percent. The ratio series is multiplied by the price series for energy consumed by all water and sanitary services companies. The index of the quantity of energy consumed by all water and sanitary services companies is retained, while price and, therefore, total cost are adjusted to a level consistent with services provided by private firms, as suggested by employment figures.

Data from the *National Energy Accounts Data Base* are currently available for 1958 through 1985. The ratio of energy cost including these data to energy cost excluding them in 1958 was multiplied by the energy cost for electric and gas utilities from 1947 to 1957 to estimate total energy costs. Similarly, the ratio in 1985 was applied in the period 1986-88. The adjustment is necessary to give energy input the appropriate weight in the aggregation of total input. It does not affect the energy input quantity index during the years 1947-57 or 1986-88, but is reflected in the series of energy input prices.

Materials input. Materials input is developed in two parts: natural gas used as a material rather than a fuel and all nongas materials. These components are combined to get total materials input. The natural gas used as a material input accounts for the majority of materials input cost and, therefore, dominates movements in the total series. This is especially true after 1973, due to the increased price of natural gas.

Gas purchased by SIC 49 is included in fuel input only if it is burned to produce heat or power. Gas destined for final consumption outside SIC 49 belongs in the materials input measure. Thus, gas used as materials input is equal to gas acquired by gas utilities, plus net withdrawals of gas previously stored, less amounts consumed within SIC 49. The American Gas Association provides all of the quantity data used in the calculation of gas materials input.[33] These data are consistent with the association's sales data, which are the basis for gas utility output data. From the total supply of gas utilities, which includes net withdrawals from storage, the amount of gas used as a fuel by electric utilities and by gas utilities is subtracted.[34] Amounts of gas ultimately sold to municipal gas companies are also subtracted, which is consistent with removal of municipal sales from output. Price series that are precisely applicable to each of the quantity series or other, proxy price series are published by the Department of Energy.[35]

The quantity and cost series for nongas materials are constructed on the basis of a series of annual input-output tables developed by BLS, using tables from the Bureau of Economic Analysis as benchmarks.[36] Because the BLS tables cover only 1947 and the period 1958-88, it was necessary to interpolate between 1947 and 1958. Current dollar cost data were used to find shares in income in 1947 and for 1958 on, and then income shares for 1948-57 were interpolated using the simple straight-line method. Quantities of each item included in materials were interpolated for the 1948-57 period. Next, total nongas materials were derived as a weighted sum of these estimated quantities. The weights were based on the estimated current-dollar expenditures on each item, derived by reflating the estimated quantities. Purchases of higher priced inputs are thereby weighted more heavily, as is appropriate for this purpose. Growth rates in the aggregate constant-dollar series are used to derive quantity indexes, and dividing these into current-dollar totals produces series of prices required for Tornqvist aggregation.

The indexes and price series for the two parts of materials input are combined prior to aggregation of total input. Thus, the results presented above refer to the combined series.

Business services input. The development of a series for business services input to SIC 49 is analogous to that for nongas materials. Services inputs shown in the BLS input-output tables are aggregated using the same methods. Data had to be estimated for 1948-57, and this was done in the same way. Aggregation of services input differs from that of nongas materials input only in the set of input-output industries whose products are included.[37]

Footnotes to the appendix

[1] There are seven three-digit utility services industries:
- 491 Electric services
- 492 Gas production and distribution
- 493 Combination electric and gas, and other utility services
- 494 Water supply
- 495 Sanitary services
- 496 Steam supply
- 497 Irrigation systems

[2] J. M. Gould, *Output and Productivity in the Electric and Gas Utilities: 1899-1942* (National Bureau of Economic Research, 1946).

[3] Yoram Barzel, "Productivity in the Electric Power Industry, 1929-1955," *Review of Economics and Statistics*, November 1963.

[4] Energy Information Administration, Office of Coal, Nuclear, Electric, and Alternate Fuels, *Statistics of Privately Owned Electric Utilities (Classes A and B Companies)* (Washington, Department of Energy, published annually).

[5] "Composite Revenues, Number of Customers, and Kilowatt-Hour Sales Reported by REA Borrowers Operating Distribution Systems," *Statistical Report, Rural Electric Borrowers* (Washington, Department of Agriculture, Rural Electrification Administration). (See also technical supplement.)

[6] Executive Office of the President, *Standard Industrial Classification Manual.*

[7] American Gas Association, *Gas Facts* (New York, American Gas Association, Inc., published annually).

[8] In 1989, 85 percent of water utility operating expenses were accounted for by publicly owned water utilities, according to *Environmental Investments: The Cost of a Clean Environment*, Report of the Administrator of the Environmental Protection Agency to the Congress of the United States, EPA-230-11-90-083 (Washington, Environmental Protection Agency, November 1990). Moreover, employment by private water and sanitary services companies never accounted for more than one-quarter of total water and sanitary services employment during the period of study, based on the labor input series and data from Bureau of the Census, *Public Employment* (Washington, Department of Commerce, annual issues, 1959-88).

[9] Bureau of Economic Analysis, *The Detailed Input-Output Structure of the U.S. Economy: 1972, Volume I: The Use and Make of Commodities by Industries* (Washington, Department of Commerce, 1979).

[10] Internal Revenue Service, *Statistics of Income . . . 1988, Corporation Income Tax Returns* (Washington, Department of the Treasury, 1991).

[11] "Implicit Price Deflators for Personal Consumption Expenditures by Product: Annually, 1929-76," *The National Income and Product Accounts of the United States, 1929-76 Statistical Tables* (Bureau of Economic Analysis, September 1981), pp. 348-52; and "Implicit Price Deflators for Personal Consumption Expenditures by Product," *Survey of Current Business* (Washington, Department of Commerce, July issues, 1982-89).

[12] Bureau of Economic Analysis, *The Structure of the U.S. Economy*, p. 163.

[13] Bureau of Economic Analysis, "Fixed Private Capital in the United States," *Survey of Current Business* (Washington, Department of Commerce, July 1985), pp. 36-59.

[14] Steven Rosenthal, *Problems in the Measurement of Land.*

[15] See William Gullickson and Michael Harper, "Multifactor productivity in U.S. manufacturing, 1949-83," *Monthly Labor Review*, October 1987, pp. 18-28.

[16] Edison Electric Institute, *Statistical Yearbook of the Electric Utility Industry* (Washington, Edison Electric Institute, published annually); Rural Electrification Administration, *Statistical Report, Rural Electric Borrowers* (Washington, Department of Agriculture, published annually).

[17] *Employment, Hours, and Earnings, United States, 1909-90, Volume II* (Bureau of Labor Statistics, March 1991), p. 720.

[18] American Gas Association, *Gas Facts.*

[19] See technical supplement to *Multifactor Productivity in Utility Services Industries*, unpublished BLS report.

[20] *Employment, Hours, and Earnings*, pp. 719-28.

[21] See technical supplement to *Multifactor Productivity in Utility Services Industries.*

[22] *Employment, Hours, and Earnings*, pp. 719-28.

[23] See technical supplement to *Multifactor Productivity in Utility Services Industries.*

[24] Bureau of Economic Analysis, "Table 6.4B-Compensation of Employees by Industry: Annually, 1948-82," *The National Income and Product Accounts of the United States, 1929-82, Statistical Tables* (Washington, Department of Commerce, September 1986).

[25] Energy Information Administration, Office of Coal, Nuclear, Electric, and Alternate Fuels, *Monthly Report for Electric Utilities R002, Fuel Consumption and Stock (II)* (Washington, Department of Energy, 1990).

[26] Edison Electric Institute, *Statistical Yearbook.*

[27] Energy Information Administration, Office of Energy Markets and End Use, *Monthly Energy Review* (Washington, Department of Energy, published monthly).

[28] Energy Information Administration, Office of Oil and Gas, *Natural Gas Annual* (Washington, Department of Energy, 1982-89).

[29] Office of Business Analysis, Under Secretary for Economic Affairs, *National Energy Accounts Data Base* (Washington, Department of Commerce, February 1985).

[30] Office of Business Analysis, *National Energy Accounts.*

[31] *Ibid.*

[32] Bureau of the Census, *Public Employment* (Washington, Department of Commerce, 1959-88), annual issues.

[33] American Gas Association, *Gas Facts.*

[34] Technically, gas used for fuel by water and other sanitary services industries should be deducted from total supply in this derivation of gas materials input. However, analogously to the development of energy input, this would be accomplished by applying a ratio based on 1958-85 *National Energy Accounts* data to the entire gas materials input

series. Because the amounts involved are not significant (the 1985 ratio would be 0.997), this approach has been avoided.

[35] Energy Information Administration, *Natural Gas Annual*.

[36] Input-output tables are available for the years 1947, 1958, 1963, and every year between 1967 and 1980. BLS modifies the published tables for mutual consistency and to reflect establishment output concepts; for those years that lack published tables, estimates are obtained by interpolation using annual control totals for gross output, final demand, and value added. See, for example, Bureau of Economic Analysis, *The Detailed Input-Output Structure of the U.S. Economy, 1977, Volume 1, The Use and Make of Commodities by Industries* (Washington, Department of Commerce, 1984).

[37] Services consist of communications; finance and insurance; real estate rental; hotel services; repair services; business services, including equipment rental, engineering and technical services, and advertising; vehicle repair; medical and educational services; and purchases from government enterprises.

Decade of children and the family

It is vexing to see decades labeled according to a single mood—the swinging sixties, the greedy eighties. The shift of a digit on the calendar year can hardly cause such a profound swing in the national psyche, only a fraction of the population. Nevertheless, the 1990s will be dedicated in a major way to children and family because family life will be at its peak for the most influential generation in the population—influential by virtue of its size and now aging into positions of influence. This shift cannot help but influence fertility decisions at the margin. Thus, other things being equal, we will probably see a somewhat higher fertility rate. How high cannot be predicted, but it will probably not be very much higher than the 2.2 in the high-fertility projection series, since the opportunity costs of having children are more likely to increase than to decrease.

——Martha Farnsworth Riche

"Demographic Change and the Destiny of the Working-Age Population." *As the Workforce Ages: Costs, Benefits & Policy Challenges*, Olivia S. Mitchell, editor. (Ithaca, NY, ILR Press, School of Industrial and Labor Relations, Cornell University, 1993), p. 24.