Data sources and methods for measuring multifactor productivity in the utility services industries (SIC 49).

I. Measurement framework

Definitions

Multifactor productivity is defined as output per unit of combined inputs of capital, labor, energy, materials, and purchased business services. Since MFP growth is being measured for a small group of industries here, it is particularly important that intermediate inputs--energy, materials, and services--are explicitly included.[1]

Including intermediate inputs implies a broad definition of output. Gross output would equal all sales by utilities, including those to other utilities. We develop measures of "sectoral output," defined as sales to customers *outside* the utility services sector, intra-industry sales being omitted. Sectoral output differs from gross output in that it avoids double counting of *intra*-industry transactions. These transactions are important for electric and gas utilities due to substantial amounts of gas and electricity resold among utilities, and to consumption of gas by electric utilities. Intra-industry sales of gas and electricity are excluded from input as well as from output.

[1] Measures of productivity for large sectors of the economy may be defined in terms of real value added output relative to labor and capital inputs. Because most intermediate inputs are both produced and consumed within large sectors, value-added measures avoid double counting of intermediate transactions. But for MFP measures of smaller groups of industries, such as the utilities sector, if intermediates were omitted, any economies or diseconomies in their use would not be reflected in the productivity measure.

Utility companies are typically engaged in two major types of activities: the delivery of utility services and the 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.[2]

Computations

The measure of multifactor productivity is an index computed by chaining annual rates of multifactor productivity growth. The MFP growth rate is computed as the rate of growth in sectoral output less the rate of growth in combined, or "aggregate", inputs:

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

where: $\Delta \ln$ 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 of aggregate input, I, is computed as a Tornqvist index of the five major types of inputs, as follows.[3] First, annual rates of growth in aggregate input are computed:

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[2] This is the way construction is handled by the Bureau of Economic Analysis of the U.S. Department of Commerce in their input-output analysis.

[3] 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.

$$\Delta \ln I = \Sigma_i \, w_i \, \Delta \ln X_i, \qquad (2)$$

where: $\Delta \ln$ 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:

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

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

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

Each major input measure is a Tornqvist index 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 which source data permit.

Similarly, total output is computed as a Tornqvist aggregate of quantity indexes for the output of each utility service, where weights are derived from the prices and quantities of the various types of services.

The multifactor productivity index (A) is constructed from the MFP growth rates ($\Delta \ln A_t$) of formula (1) in the same way that the aggregate input index (I) was computed:

$$A_t = A_{t-1} e^{\Delta \ln A_t}.^{4} \qquad (5)$$

II. Data sources and detailed methodology

Following are descriptions 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.[5] In particular, the electricity sales data include sales of electricity by combination electric and gas companies. Similarly, sales of gas by combination utilities are included in the gas data. When summed, the measures developed separately for electric utilities and gas utilities encompass SIC industries 491 to 493.

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[4] The MFP index may also be computed as the ratio of the index of sectoral output (Y) to the index of aggregate input (I), or Y/I.

[5] 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

Output measures

Output - Electric services

Electricity output is measured in kilowatt hours (KWH). Since the utilities are engaged in distribution as well as generation of electricity, output is based on KWHs sold to ultimate consumers, not KWHs generated. Although electricity might 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, with resulting lower unit cost, than residential customers; the unit cost of distribution is inversely related to quantity supplied. For this reason most electric utilities employ a rate structure distinguishing several classes of service. In the aggregation of electric services output, KWHs sold to each class of service are weighted by the price of that service, in order to take account of differences in relative unit costs.

The cost of generating electricity at a given plant will vary with the time of day or season of the year. It is generally higher during a "peak load" period, primarily because equipment may be called into service which is less efficient due to age or because it requires a more expensive type of fuel. Industrial customers are sometimes able to pay lower rates by scheduling work to take advantage of off-peak 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.[6]

The price-weighted output measure reflects variable distribution costs, as well as rate differences among service classes that are related to generation cost. It prevents bias in productivity measures due to changes in the distribution of sales among service classes. For example, if output were defined as unweighted KWH sales, productivity gains would be incorrectly inferred if consumption shifted toward the low cost industrial service.[7]

Development of output as described above is made possible by excellent source data. The Energy Information Administration (EIA) of the U.S. Department of Energy (DOE) publishes electricity sales and revenues by class of service for "selected investor-owned electric utilities."[8] These

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

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

[8] Energy Information Administration, Office of Coal, Nuclear, Electric, and Alternate Fuels, Electric Sales and Revenue, 1999, (Washington, U.S. Department of Energy, October, 2000).

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 (REA), and is used to supplement the DOE data.[9]

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

Output - Gas services

By definition, gas utility services include transmission, storage, and distribution of natural gas for sale, as well as production and or distribution of manufactured, mixed, and liquefied petroleum (LP) gas.[10] In 1947 natural gas accounted for 87% of gas supply, with manufactured and mixed gas contributing 8% and 5% of sales,

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[9] "Composite Revenues, Number of Customers, and Kilowatt-Hour Sales Reported By REA Borrowers Operating Distribution Systems," *Statistical Report, Rural Electric Borrowers* (Washington, U.S. Department of Agriculture, Rural Electrification Administration).

[10] Executive Office of the President, Office of Management and Budget. *Standard Industrial Classification Manual*. Distribution of LP gas in steel containers is classified in SIC industry 5984.

respectively. By 1955 manufactured gas contributed less than one percent of output and the share of natural gas had climbed to 95%. More than 98% of U.S. gas supply was natural gas in 1975, and 99% in 1994. In this study, gas service output is defined as natural gas delivered to final consumption, with adjustments to adhere to the sectoral output concept within the privately-owned utility industry.

The distribution component of gas service prevents it being a homogeneous product, and gives rise to large differences in gas prices facing various categories of customers. In aggregating output, the quantity of deliveries in each category is weighted by its price, yielding an index of output that recognizes the different costs of distribution. Data on deliveries and prices for residential, commercial, and industrial customers are available for the period 1930-98 in Natural Gas Annual, published by the Department of Energy.[11]

Since we have designed the gas output series to be a constituent part of the overall sectoral output series for

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[11] Energy Information Administration, Office of Oil and Gas, "Table 94. Natural Gas Consumption in the United States, 1930-1999," and also "Table 95. Average Price of Natural Gas Delivered to U.S. Consumers, 1967-1999," *Natural Gas Annual 1999* (Washington, U.S. Department of Energy, October 2000).

Definition of gas output as deliveries rather than sales resulted from changing the source of gas output data, and represents a change from previous versions of this measure. In recent years, a growing proportion of natural gas is purchased from non-local utilities. DOE deliveries include these transactions, whereas the American Gas Association sales data used previously excluded them.

all utility services, sales of gas to electric utilities must not be included. Sales of gas for electricity generation and corresponding revenues are reported separately, and so may be omitted during the aggregation of output. Analogous to the case of electricity output, purchases of gas by publicly-owned electric utilities would ideally be included in output, but, due to data limitations, they are removed along with the much larger amounts of gas sold to privately-owned electric utilities.

Gas sold by municipally-owned gas companies must be removed to limit the output measure to the private sector. Natural gas sales and revenue data are available by type of ownership from the American Gas Association (AGA). Municipal gas sales are published for 1974 through 1998 in Gas Facts.[12] Corresponding revenue data were provided for 1980 to 1996. Prior to 1974, municipal gas sales could be derived by deducting sales by private gas companies from sales by all gas companies. Detailed sales by class of customer for 1974-84 revealed that the distribution of total municipal gas sales among the four service classes was nearly constant over that period. Total municipal sales in each year 1948-73 were distributed based on the average percent distribution 1974-84, then estimated sales by class of service 1948-73 were multiplied by the average price of all gas sales by class to estimate revenues by class.

[12] American Gas Association, "Table 6.2 Gas Utility Industry Sales, by Class of Service and Type of Company, 1992-98," *Gas Facts, 1999*,(Washington, The American Gas Association, 1999).

1996 was the last year for which the AGA has revenue data corresponding to municipal gas sales, so values for 1997 and 1998 had to be estimated. Ratios equal to the price of gas sold by municipally-owned gas companies divided by the average price of sales by all privately-owned companies were computed for each class of service for the year 1996. These ratios were multiplied by the average price of private sales in 1997 and 1998 to estimate the price of municipal sales for each class of service. Revenues from sales by municipal gas companies, by service class, were estimated as the product of sales and price.

Because AGA reports amounts of natural gas in British Thermal Units (BTU) and DOE reports million cubic feet, it is necessary to convert AGA data for the entire period 1948-98 to million cubic feet using a DOE series of conversion factors.[13] Finally, both sales and revenues of the municipal gas companies 1948-98 are subtracted from output, by class of customer.

Electricity and gas sales to privately-owned water and sanitary services companies would ideally be excluded from the output measure. Sales to for private companies are not reported separately from sales to publicly-owned firms, which account for a large majority of these transactions.[14]

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[13] Energy Information Administration, Office of Energy Markets and End Use, "Table A4. Approximate Heat Content of Natural Gas (Btu per cubic foot)," *Monthly Energy Review* (Washington, U.S. Department of Energy, published monthly).

Electricity and gas consumed by private water and sanitary services companies are not deducted, but the overstatement of output is insignificant. For example, *total* water and sanitary services industry consumption of electricity and gas of 12.7 million dollars in 1972 was just 0.03 percent of the 37.446 billion dollars in sectoral output of the private utilities services industry.[15]

Output - 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 to 497).[16] Actually, data for 1947 to 1957 cover water services only, but all of the above are reflected in 1958 to 1997 data. The data are based on income tax returns of a sample of corporations, which changes from year to year.

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[14] 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 W&SS companies never accounted for more than one quarter of total W&SS employment during the period of study, based on the labor input series and data from; Bureau of the Census, *Public Employment*, (Washington, DC, U.S.Department of Commerce), annual issues 1959-88.

[15] 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, U.S. Department of Commerce, 1979).

[16] Internal Revenue Service, *Statistics of Income, Corporation Income Tax Returns*, selected years, 1948-97,(Washington, U.S. Department of the Treasury, 1951-2000).

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 (BEA).[17] The constant dollar revenue series is then indexed, and used to complete the aggregation of total utility services output. The IRS data do not permit us to subtract intra-industry consumption of water and other sanitary services. However, in 1992 electric and gas utilities purchased less than one-half percent of water and other sanitary services output.[18]

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, inventories, and land. Investment in these

[17] "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. 348-352; and "Table 7.5-Implicit Price Deflators for Personal Consumption Expenditures by Product," *Survey of Current Business* (Washington, U.S. Department of Commerce, July issues 1982-94 and 1999, August issues 1996-97).

[18] Bureau of Economic Analysis, *Benchmark Input-Output Accounts of the United States, 1992, Table 2.1: The Use of Commodities by Industries*, (Washington, D.C.: U.S. Government Printing Office, September 1998).

capital assets is published by the Bureau of Economic Analysis at roughly the 2-digit SIC level.[19] The Bureau of Labor Statistics has developed capital stock measures for each of 44 types of depreciable assets (equipment and structures) within SIC industry 49 by applying the perpetual inventory method to the BEA investment data. This 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 National Income and Products Account (NIPA) data, published by BEA.

The stock of land owned and used by SIC 49 and other industries is estimated as follows. Nonfarm land is estimated by applying ratios of land to structures, obtained from the Bureau of the Census, to the BLS value of structures series. Total nonfarm land is allocated to 2-digit SIC industries based on book values of land, published in *Statistics of Income* by the U.S. Treasury Department.[20]

Source data for 44 distinct capital asset types contribute to the capital stock measure for SIC industry 49. Stocks of the several assets are combined using weights

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[19] Bureau of Economic Analysis, *Fixed Reproducible Tangible Wealth in the United States, 1925-94* (Washington, U.S. Department of Commerce, August 1999).

[20] Internal Revenue Service, *Statistics of Income, Corporation Income Tax Returns*, selected years, 1948-97 (Washington, U.S. Department of the Treasury, selected years, 1951-2000).

derived from estimates of implicit rental prices -- the prices that the various types of capital would bring on a hypothetical rental market. These rental prices are estimated by comparing capital stocks to NIPA estimates of property income in SIC 49. For each type of asset, a structured rental price formula is used, consisting in part of a rate of return on the asset, plus a rate of depreciation, minus the asset's rate of price appreciation. Using these rental prices, Tornqvist aggregation is applied to the individual assets, resulting in a quantity index for real capital input.

The price of capital is derived by dividing SIC 49 property income by the quantity index. This price is used when aggregating capital with other inputs.[21]

Labor input

The units of measure of labor input are hours worked, where hours worked by all types of workers are counted equally. The scope of labor input is limited to utility operations and maintenance workers, with the intention of excluding any labor devoted to new construction. This is consistent with definition of output as delivered utility services, rather than a broader concept inclusive of structures completed or in progress. Study of MFP growth is

[21] "Revisions to Capital Inputs for the BLS Multifactor Productivity Measures". 6 May 1998. Available online: [http://stats.bls.gov/mprcaptl.htm].

thereby confined to the primary function of utilities, provision of electric, gas, water, or other services. This is a significant matter in the electric utility industry where 15 percent (1996) of employees are construction workers. Thus, a desirable characteristic of source data for electric utility labor input is that it distinguishes construction workers from the rest.

Sources of employment data for electric utilities are the statistical yearbooks of Edison Electric Institute (EEI) and the Rural Electrification Administration (REA).[22] Only the Edison Electric Institute Statistical Yearbook breaks out employment into operations, maintenance, and construction workers, but it covers practically the entire (98%) private industry. Moreover, it is reasonable to believe that the REA borrowers employ a smaller percentage of construction workers than the large utilities. Here it is assumed there are none. The EEI employment data extend back to 1951, and percent changes in SIC 491 employment from the BLS establishment survey were used to move the EEI series from 1951 back to 1947.[23] Edison Electric Institute stopped reporting electric utility employment by type after data year 1989. However, they still provide salary by type

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

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

of worker to date, making it possible to break out total employment into construction and operations & maintenance with reference to wage rates, as has always been necessary for gas utilities. Briefly, wages of operations and maintenance workers, and construction workers, are assumed to grow at the same all-employee rate. Estimated wages 1990-98 are divided into payroll in each category, to estimate employment. The sum of employment in the two categories is then benchmarked to total employment, a published series.

The total employment series published by EEI was changed from an annual average to a year-end concept staring with data for 1995.[24] The ratio of 1994 average to year-end employment (1.027) is being used to scale up levels for 1995 and subsequent years. This adjustment only affects the annual change in labor input from 1994 to 1995.

Source data for gas utility employment 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 period by AGA. As in the case of electric utilities, it is necessary to estimate and subtract out construction labor. The AGA

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[24] Op. Cit., Edison Electric Institute.

reports payroll data broken out into operations, construction, and miscellaneous categories, starting with 1971 for the investor owned part of the industry and in 1947 at the total industry level.[25] 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 private gas utility construction employment was derived back to 1972, the first year for which SIC 162 average weekly earnings are reported by BLS in Employment, Hours, and Earnings.[26] Subtraction of this series from the total employment series yields estimated non-construction employment for 1972-98. An alternative estimate of non-construction employment was based on the assumption that construction workers in gas utilities earn the industry average wage, so that total employment can be distributed between construction and non-construction in the same proportion as the payroll. This method produces a series that moves in the same direction as the first in every year. We use movements in this series to complete the measure of non-construction employment in investor owned gas utilities since it covers a longer period.

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[25] Op. Cit., American Gas Association.

[26] *Employment, Hours, and Earnings, United States, 1909-90, Volume I* (Bureau of Labor Statistics, March 1991), p. 48., and *Employment, Hours, and Earnings, United States, 1988-96,* (Bureau of Labor Statistics, August 1996), p. 17; and "Table B15. Average hours and earnings of production and nonsupervisory workers on private nonfarm payrolls by detailed industry," *Employment and Earnings,* (Bureau of Labor Statistics, March 1998-99).

Employment in the other utility services, encompassing SIC industries 494-497, is found as the residual of employment in industry 49 less that in industries 491-493. All of the required data appear in Employment, Hours, and Earnings except for employment in SIC 492 and SIC 493 during 1947-49.[27] Stable employment trends in these industries during the early 1950's were utilized in an estimation of these values. In the absence of evidence of construction labor in these industries, it is assumed there are none. Employment in SIC industries 494-497 is very small relative to that in electric and gas utilities, averaging about ten percent of the industry 49 total, so that a fairly stable proportion of employees devoted to construction would not significantly affect the two-digit labor input trend.

Employment is next multiplied by average weekly hours to estimate paid hours. Average weekly hours of nonsupervisory workers are reported in Employment, Hours, and Earnings by three-digit SIC industry, with data beginning in 1947 for SIC 491 and in 1950 for industries 492 and 493.[28] These three industries, when combined, cover all

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[27] *Employment, Hours, and Earnings, United States, 1909-90, Volume II* (Bureau of Labor Statistics, March 1991), p. 719-28,and *Employment, Hours, and Earnings, United States, 1988-96* (Bureau of Labor Statistics, August 1996), p. 270-73; and "Table B12. Employees on nonfarm payrolls by detailed industry," *Employment and Earnings,* (Bureau of Labor Statistics, March 1998-99).

[28] *Employment, Hours, and Earnings, United States, 1909-90, Volume I* (Bureau of Labor Statistics, March 1991), p. 48., and *Employment, Hours, and Earnings, United States, 1988-96,* (Bureau of Labor Statistics, August 1996), p. 17; and "Table B15. Average hours and earnings of production and nonsupervisory workers on

the private electric and gas utilities. Because the employment data for electric and gas utilities are developed separately, and SIC 492 includes both electric and gas utilities, average weekly hours cannot be applied at the three-digit level. Therefore an average weekly hours series for SIC industries 491-493 combined is derived.

Average weekly hours for SIC 491-493 combined are found by first multiplying average weekly hours of nonsupervisory workers by employment in each industry to get hours. Then these data are summed over industries 491-493. The sum of hours in SIC 491-493 is subsequently divided by the sum of nonsupervisory employment to get an average weekly hours figure for electric and gas utilities together. Note that it was necessary to assume that average weekly hours in industries 492 and 493 were the same in 1947-49 that they were in 1950. Paid hours in electric and gas utilities are the product of their summed employment and this combined average weekly hours series.

Hours for the remaining industries in total industry 49 are found as the residual of total employee hours in SIC 49 less hours in SIC 491-493. It was necessary to estimate average weekly hours in SIC 49 for 1947-57 using forecasting methods and three-digit level data. The hours series so obtained for SIC 494-497 is based entirely on published data. Unpublished BLS data also permit direct calculation

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private nonfarm payrolls by detailed industry," *Employment and Earnings,* (Bureau of Labor Statistics, March 1998-99).

of hours for industries 494-497 back to 1972. Differences between the two alternative series since 1972 are very small. Since the series we estimated using published data would have to be used for years prior to 1972 in any case, it is used for the entire 1947-98 period. This series is added to the non-construction worker hours series for SIC 491-493 to derive a paid hours series for the utility services industries.

Finally, this paid hours series is multiplied by a series of ratios of hours worked to hours paid to obtain the desired measure of labor input, hours worked by utility non-construction workers. Hours worked to hours paid ratios are produced by the BLS Hours at Work Survey.[29] Because the ratios are different in each year 1966-98, year-to-year changes in labor input, output per hour, and MFP were potentially impacted by this adjustment. The 1966 ratio is held constant for the years 1947-66, so there was no impact on annual changes in these measures during that period.

The weights used to combine labor hours with other inputs are based on current-dollar payments to labor. Total labor compensation is appropriate for use in the multifactor

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[29] Kunze, Kent, "A new BLS survey measures the ratio of hours worked to hours paid," *Monthly Labor Review*, Vol. 107 No. 6 (Washington, U.S. Department of Labor, Bureau of Labor Statistics, June 1984).

Jablonski, Mary and Kent Kunze and Phyllis Flohr Otto, "Hours at work: a new base for BLS productivity statistics," *Monthly Labor Review,* Vol. 113 No. 2 (Washington, U.S. Department of Labor, Bureau of Labor Statistics, February 1990).

productivity framework, in order to account for all costs of production. Data used to estimate compensation at investor-owned electric utilities are wages of Operations and Maintenance workers 1947-96 as reported by DOE, and wages of Operations and Maintenance workers, and Other workers, 1989-98, as reported by Edison Electric Institute (EEI). Data from both of these sources are ultimately derived from Federal Energy Regulatory Commission (FERC) Form 1. Because we prefer the more inclusive definition including Other workers, the ratio of EEI wages over DOE wages in 1989 is multiplied by the DOE amounts in each year 1947-88.

The FERC-based data do not cover wages of employees at Rural Electrification Administration (REA) electricity generators and distributors. Therefore, the ratio of electric utility employment including REA employment over employment excluding REA workers is multiplied by the EEI/DOE wage series in each year 1947-98 to scale it up. The implicit assumption is that rural electric employees are paid similar wages to employees of larger utilities covered by the FERC survey.

Wages of non-construction workers at investor-owned gas utilities must also be incorporated. Wages of Operations and Maintenance, and Miscellaneous, workers are published by AGA for the entire 1947-98 period, and are used as

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Zegeye, Aklilu and Larry Rosenblum, "Hours at Work Survey, 1999." Available online: [http://stats.bls.gov/pdf/mprhws.pdf].

reported.[30] BLS reports wages by 3-digit SIC industry within this industry group (SIC 49) in the annual publication Employment and Wages. Wages for SIC industries 494 to 497 are summed to obtain wages of workers in sanitary services industries, which are added to those for electric and gas utilities.

The Bureau of Economic Analysis(BEA) of the Commerce Department publishes wages and salaries, and also supplements to wages and salaries, for SIC industry 49.[31] These data cannot be utilized directly because they reflect payments to construction workers, but they suggest the amount that supplementary payments contribute to compensation. We compute the ratio of total compensation to wages & salaries from the BEA data and apply it to our wage & salary estimate, in each year. The resulting series is an estimate of total compensation of non-construction workers in utility services industries. Division of this series by the hours index yields the labor price series required for Tornqvist aggregation of total input.

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[30] American Gas Association, “Table 14.2 Gas Utility Industry Employees and Payroll by Type of Payroll and Type of Company, 1985-98,” *Gas Facts*, *1999*,(Washington, The American Gas Association, 1999).

[31] 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, U.S. Department of Commerce, September 1986). Recent and revised data available online: [http://www.bea.doc.gov] in section titled, "Gross Product by Industry and the components of gross domestic income."

Energy input

Electric utilities account for a large majority of energy input expenditures by SIC industry group 49.[32] Energy input to electric utilities consists primarily of fossil fuels burned to drive electricity generating plants. Electric utilities also produce electricity from water, wind, solar, and geothermal power. These are energy inputs too. On the other hand, electricity is produced using nuclear fuel, yet nuclear fuel is included in capital input. The long useful life of this energy source, about five years, suggests treating it as a depreciable capital asset.

Fossil fuels used to generate electricity are coal, oil, and gas. 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 pipelines and 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 by gas utilities to gas producers in SIC

[32] Ninety-three percent in 1960 and 1970, ninety-one percent in 1985, and eighty-eight percent in 1996.

industry 13, rather than the considerably higher price paid to gas utilities by electric utilities.[33]

The Energy Information Administration of DOE provides data on quantities of coal, oil, and natural gas consumed by privately owned electric utilities from 1970 forward.[34] These three series were extended back to 1947 based on closely related information available in the EEI statistical yearbook.[35] There one finds 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. Of the latter, we used electricity generation driven by conventional (versus nuclear) steam engines and turbines, and by internal combustion engines, because these are the prime movers which consume fossil fuels. These 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 consumption of each fossil fuel by all electric utilities,

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[33] Energy Information Administration, Office of Oil and Gas, "Table 92. Quantity and Average Price of Natural Gas Production in the United States, 1930-1999," and also “Table 95. Average Price of Natural Gas Delivered to U.S. Consumers, 1967-1999," *Natural Gas Annual 1999* (Washington, U.S. Department of Energy, October 2000).

[34] Energy Information Administration, Office of Coal, Nuclear, Electric, and Alternate Fuels, *Monthly Report for Electric Utilities R002, Fuel consumption and stock(II)* (Washington, U.S. Department of Energy).

[35] Edison Electric Institute. *Statistical Yearbook of the Electric Utility Industry* (Washington, Edison Electric Institute).

giving estimated private fuel consumption. Estimated values for 1970-88 were compared to actual fuel consumption data provided by EIA, 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 "average wellhead price of marketed production", published in Monthly Energy Review by DOE.[36]

Natural gas which is transported through gas pipelines and utilities to final consumers outside industry 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 forward, and corresponding prices from 1967 forward.[37] Here again the price of marketed production is used 1947-57. The price of pipeline fuel from 1958 to 1966

[36] Energy Information Administration, Office of Energy Markets and End Use, *Monthly Energy Review* (Washington, U.S. Department of Energy).

[37] Energy Information Administration, Office of Oil and Gas, *Natural Gas Annual* (Washington, U.S. Department of Energy, 1982-99).

is reported in the National Energy Accounts, available from the U.S. Department of Commerce.[38] This is also the source of price and quantity data 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.[39]

Energy input for the remaining utility services industries is provided in the National Energy Accounts (NEA).[40] NEA data are organized primarily by BEA Input-Output industry, but a single industry classification corresponds to SIC industries 494 to 497; water supply and sanitary services (W&SS). The substantial detail describes how each of several types of fuel was used, the quantities used in physical units, and the cost both in current and constant dollars. Eight different petroleum products are Tornqvist aggregated to get fuel input to industries 494 to 497.

However, the NEA data reflect 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

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

[39] Ibid.

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

ratio of employment by private W&SS companies to employment at all W&SS companies is taken as an indicator of the portion of energy consumption attributable to the private firms. Development of private employment based on published BLS data has been described previously. Government employment in water and sanitary services is available from the Bureau of the Census.[41] 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 Divisia price series for energy consumed by all water and sanitary services companies. The index of the quantity of energy consumed by all W&SS companies is retained, while price and therefore total cost is adjusted to a level consistent with services provided by private firms, as suggested by employment.

NEA data 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 1947-57 to estimate total energy costs. Similarly, the ratio in 1985 is applied in 1986-98. 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 1986-98, but is reflected in the series of energy input prices.

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

Materials input

Materials input is developed in two parts: natural gas that is used as a material rather than a fuel, and all non-energy materials. These components are combined to get total materials input. 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 only included in fuel input if it is burned to produce heat or power. Gas that is destined for final consumption outside industry 49 belongs in the materials input measure. A measure of gas used as materials input is derived by first adding to "dry" gas production withdrawals of gas previously stored, and imports. This is the amount of natural gas available for ultimate consumption. Next, amounts consumed within industry 49 for electricity generation, and for gas plant and pipeline use, are deducted. The Department of Energy provides the required data, which are consistent with the DOE data from which we compute gas utility output.[42] It is also necessary to subtract gas sold by municipally owned gas companies from gas materials input. This step corresponds

[42] Energy Information Administration, Office of Oil and Gas, *Natural Gas Annual* (Washington, U.S. Department of Energy, 1982-99).

to exclusion of these transactions from output, and uses the same AGA data.[43] It only differs in that municipal sales, once converted from Btu to million cubic feet, are subtracted out in total, not by customer category.

Price series which are either precisely applicable to each of the quantity series, or are good proxies, are published by DOE in Natural Gas Annual.[44]

The quantity and cost series for non-energy materials are constructed based on a series of annual input-output (I-O) tables developed by BLS, using BEA I/O tables as benchmarks.[45] Because the BLS I-O tables only cover the year 1947 and the period 1958-90, it was necessary to interpolate between 1947 and 1958, and extrapolate from 1990 forward. When I/O benchmark data for 1995 become available, estimates for recent years will be revised.

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[43] Energy Information Administration, Office of Oil and Gas, *Natural Gas Annual* (Washington, U.S. Department of Energy, 1982-99). Gas used for fuel by water and other sanitary services industries should technically be deducted from total supply in this derivation of gas materials input. However, analogous to the development of energy input, this would be accomplished by applying a ratio based on 1958 to 1985 NEA data to the entire gas materials input series. Because the amounts involved are not significant (the 1985 ratio would be 0.997) we have not done so.

[44] Op. Cit., Energy Information Administration, Office of Oil and Gas.

[45] Input-output tables are presently available for the years 1947, 1958, 1963, and for every year between 1967 and 1980. BLS modifies the published tables for mutual consistency and to reflect establishment output concepts; for years lacking published tables, estimates are obtained by interpolation using annual control totals for gross output, final demand, and value added. 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, U.S. Department of Commerce, 1984).

Current-dollar purchases were used to find shares in SIC 49 income in 1947 and for 1958-90, then the 1948-57 shares were interpolated using the simple straight-line method. Current-dollar purchases could then be estimated as the product of income share and total income for each product in each year from 1948 to 1957. Quantities of each item included in materials were then estimated by deflating the current-dollar data using available BEA prices. Next, a series of annual rates of growth in total non-energy materials was derived as a weighted sum of changes in these quantities, where the weights were based on the estimated current-dollar expenditures on each item. Purchases of higher priced inputs were therefore weighted more heavily, as is appropriate. Growth rates in the aggregate constant-dollar series were used to construct a quantity index, one year at a time, from 1948 to 1990. Finally, dividing this index into total current-dollar purchases produced the corresponding price series.

For 1991 to 1998, the share in income of non-energy materials is held constant at the 1990 value. This share is multiplied by current-dollar output in SIC 49 to estimate current-dollar expenditures on non-energy materials. Then the current-dollar series is deflated using a composite price deflator based on prices provided by the Office of Employment Projections (OEP). Because data for 1948-90 utilize BEA prices, the ratio of the BEA price to the OEP

price for 1990 is multiplied by the OEP price in each year 1991-96, to link to the existing price series.

Quantity data for 1991-98 are estimated as current-dollar data divided by the adjusted price series. Indexes and price series for the two types of materials input are combined prior to aggregation of total input.

Business services input

The development of a series for business services input to industry 49 is analogous to that of non-energy materials, described above. Services inputs from BLS input-output tables are aggregated using the same methods, including estimation of data for 1948-57. Estimation of post-1990 data is done in the same way, but using a composite price deflator reflecting the appropriate OEP price series. Aggregation of business services input differs from that of non-gas materials input only in the set of I-O industries whose products are included.[46]

[46] Services consist of the following: 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.