Multifactor Productivity Measures for Three-digit SIC Manufacturing Industries

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Multifactor productivity increased over the 1987-96 period in 63 of the 108 industries for which the Bureau of Labor Statistics (BLS) publishes data. (See table 1.) Most of the gains were relatively modest. Average annual increases of between 0.1 and 1.0 percent were recorded in 32 industries. In another 21 industries, multifactor productivity rose by more than 1.0 percent but the increase did not exceed 2.0 percent. Ten industries had growth rates exceeding 2.0 percent, including the two industries whose growth rates far exceeded those of all other manufacturing industries—electronic components and accessories, at 14.8 percent, and computer and office equipment, at 14.4 percent.

This report presents data on multifactor productivity and related series for the years 1987 to 1996. These series have been prepared for all 140 three-digit SIC manufacturing industries. Data are presented here for the 108 industries for which data are published. Unpublished series for the remaining industries are available upon request. Published indexes for multifactor productivity and related series also are available at **http://stats.bls.gov/iprhome.htm**. E-mail requests for information may be sent to ***dipsweb@bls.gov***. Data for the 1997-99 period will be available in the latter part of 2001.

Methods and data sources

Multifactor productivity indexes relate the change in output to the change in the combination of labor, capital, and intermediate purchases inputs consumed in producing that output. Because they incorporate a measure of combined inputs, multifactor productivity measures are not influenced by the substitution of capital and intermediate inputs for labor, as are measures of labor productivity. Multifactor productivity is calculated by dividing a Tornqvist index of output by a Tornqvist index of combined inputs.[1]

Output. Output quantities for most industries are based on the value of output adjusted for price change. The value of shipments of primary products, wherever made, for each product class is taken from the U.S. Census Bureau's Annual Surveys of Manufactures (ASM). These product class values are deflated with matching BLS producer price indexes (PPIs) and are Tornqvist-aggregated to the four-digit SIC industry level. For each year, special coverage ratios for the industry are used to adjust the wherever-made indexes to an industry basis. The resultant industry indexes are further adjusted to reflect changes in inventories to yield a measure of production during the given year.

Every 5 years, BLS develops benchmark output indexes that incorporate data from the Censuses of Manufactures (CM), which are more detailed than those available in the ASMs. Adjustments are derived from these data to remove resales and intra-industry transactions in order to avoid double counting of output. The annual output indexes based on ASM data are adjusted to the quinquennial benchmark levels by linear interpolation.

Each four-digit industry output index is Tornqvist-aggregated to the three-digit industry level. In the process of this last aggregation, adjustments are developed to remove a second level of double counting—those transactions between four-digit industries within the same three-digit industry.

Combined inputs. The index of combined inputs is a Tornqvist aggregate of separate indexes of labor input, capital input, and intermediate purchases input. The labor share weight is based on the total value of labor compensation including fringe benefits. The intermediate purchases share weight is based on the total value of materials (adjusted to remove intra-industry transactions), fuels, electricity, and purchased services. The capital share weight is a residual calculated as the value of net production minus the value of labor compensation minus the value of intermediate purchases.

Labor input. The labor input indexes are developed by dividing the aggregate employee hours for each year by the base-period aggregate. Because of data limitations, employee hours are treated as homogeneous and additive, with no distinction made between hours of different groups of employees. Annual hours of all employees are derived by summing the aggregate hours for production workers and the estimated hours for nonproduction workers. Data on employment and hours are based on BLS surveys.

[1] A Tornqvist index of output is developed by computing a weighted average of the growth rates of the various industry products between two periods, with weights based on the products' shares in industry value of production. The weight for each product equals its average value share in the two periods. For a more complete discussion of the Tornqvist methodology see Kent Kunze, Mary Jablonski, and Virginia Klarquist, "BLS modernizes industry labor productivity program," *Monthly Labor Review*, July 1995, pp. 3-12.

Capital. The measure of capital input is based on the flow of services derived from the stock of physical assets. Physical capital is composed of equipment, structures, land, and inventories. Capital services are estimated by calculating capital stocks; changes in the stocks are assumed to be proportional to changes in capital services for each asset. Stocks of different asset types are Tornqvist-aggregated using estimated rental prices to construct the weights for assets of different types.

Capital stocks are calculated using the perpetual inventory method, which takes into account the continual additions to and subtractions from the stock of capital as new investment and retirement of old capital take place. The perpetual inventory method measures stocks at the end of a year equal to a weighted sum of all past investments, where the weights are the asset's efficiency relative to a new asset. A hyperbolic age-efficiency function is used to calculate the relative efficiency of an asset at different ages. The hyperbolic age-efficiency function can be expressed as:

$$S_t = [L - t]/[L - (B)t]$$

where:

S_t = the relative efficiency of a t-year-old asset;
L = the service life;
t = the age of the asset; and
B = the parameter of efficiency decline.

The parameter of efficiency decline is assumed to be 0.5 for equipment and 0.75 for structures. These parameters yield a function in which assets lose efficiency more slowly at first, then rapidly later in life.

Price change must be removed from the investment data before stocks are calculated. Industry-specific price deflators for each asset category are constructed by combining detailed price indexes (mostly PPIs) with weights based on the capital flow tables from the U.S. Commerce Department's Bureau of Economic Analysis (BEA).[2] These deflators are used to convert the current-dollar investment to constant dollars. The investment data are broken out annually into 24 categories of equipment and 2 categories of structures. These estimates are based on the 1992 BEA capital flow table and the biproportional matrix method.[3] Service lives for the perpetual inventory are taken from those used for each asset in the two-digit SIC multifactor measures prepared by BLS.

Current-dollar values of inventory stocks are calculated for three separate categories of manufacturers' inventories: Finished goods, work in process, and materials and supplies. Inventory stocks for each year are calculated as the average of the end-of-year stocks in years t and t-1 to represent the average used during the year as a whole. This also is done with equipment, structures, and land. Inventory values for finished goods and work in process are deflated with an industry output implicit price deflator. The values of materials and supplies inventories are deflated with a deflator prepared by combining price indexes with weights based on detailed materials consumed from the CM. Land stocks are estimated as a function of the movement in constant-dollar gross structures stocks for the given industry.

The various equipment, structure, inventory, and land stock series in constant dollars are aggregated into one capital input measure, with implicit rental prices being used to construct the weights. Rental prices are calculated for each asset as:

$$RP = [(P \times R) + (P \times D) - (P^{t} - P^{t-1})] \times (1- uz- k)/(1- u)$$

where:

RP = the rental price;
P = the deflator for the asset;
R = the internal rate of return;
D = the rate of depreciation for the asset; and
$P^{t} - P^{t-1}$ = the capital gain term for the asset (an average of the current and 2 preceding years' price change.[4]

The term $(1 - uz - k)/(1 - u)$ reflects the effects of taxation where:

u = the corporate tax rate;
z = the present value of $1 of depreciation deductions; and
k = the effective investment tax credit rate.

This method of calculating rental prices is similar to that used in calculating multifactor productivity for major sectors of the economy except that no attempt is made to incorporate the effects of indirect business taxes, for which data are lacking at the industry level. Rental prices are expressed in rates per constant dollar of productive capital stocks. Each rental price is multiplied by its constant-dollar capital stock to obtain current-dollar capital costs, which are then converted to value shares for Tornqvist aggregation.

Intermediate purchases. The index of intermediate purchases input is constructed as a Tornqvist aggregate of separate indexes of change in the quantity of materials, services, fuels, and electricity consumed by an industry. Except for electricity, for which direct quantity data are available, quantities are derived by deflating current-dollar values with appropriate price deflators. Annual current-dollar values of total materi-

[2] The 1992 table is available from the BEA website: http://www.bea.doc.gov/bea/dn2.htm

[3] The biproportional matrix method produces estimates of all cells in a matrix for year $n + 1$ when a full matrix is available in year n and only row and column sums are available in year $n + 1$.

[4] See Michael J. Harper, Ernst R. Berndt, and David O. Wood, "Rates of Return and Capital Aggregation Using Alternative Rental Prices," in Dale W. Jorgenson and Ralph Landau, eds., *Technology and Capital Formation* (Cambridge, MA, The MIT Press, 1989).

als consumed for each industry come from the ASM and CM.

To avoid double counting, the materials estimates exclude, whenever possible, the value of intra-industry purchases. Estimates of materials purchased from other establishments within the industry are subtracted from the gross measure of materials costs to derive estimates of “net” materials consumed.

Constant-dollar net materials consumed by each industry are derived by dividing the annual current-dollar values by an industry-specific materials price deflator. To construct the materials price deflator, detailed producer price indexes are weighted together with weights based on the values of specific materials consumed by each industry. Data to construct these weights come from the CM and the BEA benchmark input-output tables.[5]

Annual data on the total value of all fuels consumed by industry, also from the ASM and CM, are deflated with industry-specific price deflators. Producer price indexes for six types of fuel are aggregated using weights based on the nominal values of specific fuels consumed, by industry. Data for estimating the weights are from the ASM, supplemented for some of the major energy consuming industries with data from the U.S. Department of Energy. Because both the value and the quantity of purchased electricity are available annually by industry from the ASM and CM, electricity is treated as a separate component of intermediate purchases. Estimates of price and quantity of electricity are derived directly from the ASM and CM data.

The annual cost of materials data do not include the value of purchased services. As a result, current-dollar services purchased by each industry are estimated based on proportions from the BEA benchmark input/output tables. Because of a lack of historical data on price indexes for services, the aggregate, fixed-weight materials deflator is used for deflating current-dollar services as well as materials.

[5] The most recent table is *Benchmark Input-Output Accounts of the United States, 1992* (Washington, U.S. Department of Commerce, Bureau of Economic Analysis, September 1998).

TABLE 1. **Multifactor productivity and related variables, average annual percent change, 1987-96**

SIC code	Industry	Multifactor produc-tivity	Output	Combined inputs	Labor	Capital	Inter-mediate purchases
202	Dairy products	-0.1	0.5	0.7	-1.1	1.6	0.8
203	Preserved fruits and vegetables	-.3	1.7	2.0	.7	2.1	2.2
204	Grain mill products	-.7	1.3	2.0	.5	2.5	2.1
205	Bakery products	-.4	-.7	-.3	-.2	1.9	-1.0
206	Sugar and confectionery products	2.1	1.7	-.5	.2	1.4	-1.7
207	Fats and oils	.3	1.0	.7	-.1	.3	.8
208	Beverages	1.6	2.2	.6	-1.2	-.1	1.3
209	Miscellaneous food and kindred products	.9	2.2	1.3	1.2	1.4	1.1
221	Broadwoven fabric mills, cotton	-.5	-.1	.4	-3.5	-1.9	2.2
222	Broadwoven fabric mills, manmade	1.5	.9	-.6	-3.4	.1	.3
224	Narrow fabric mills	1.9	1.3	-.6	-1.3	.6	-.5
225	Knitting mills	1.9	2.2	.3	-2.3	.8	1.4
226	Textile finishing, except wool	.9	-1.1	-2.0	1.5	-.3	-3.1
227	Carpets and rugs	.8	.3	-.5	.3	.3	-.7
228	Yarn and thread mills	-.3	1.2	1.5	-3.1	1.0	2.9
229	Miscellaneous textile goods	.2	2.2	2.0	-.1	2.3	2.6
232	Men's and boys' furnishings	-.6	-.3	.3	-3.6	.4	2.0
233	Women's and misses' outerwear	1.0	.5	-.4	-3.3	.3	.6
234	Women's and children's undergarments	-.2	-.5	-.3	-6.5	-.6	2.4
235	Hats, caps, and millinery	-1.5	.7	2.2	2.9	2.0	1.7
238	Miscellaneous apparel and accessories	-.3	-.3	.1	-2.3	-.6	1.2
239	Miscellaneous fabricated textile products	.4	2.3	1.9	1.6	2.6	1.8
242	Sawmills and planing mills	1.8	.4	-1.3	-1.2	-1.5	-1.4
243	Millwork, plywood, and structural members	-.3	-.1	.2	.8	1.4	-.2
244	Wood containers	1.0	3.4	2.3	2.6	.1	2.5
245	Wood buildings and mobile homes	-.4	2.5	2.9	2.9	.1	3.5
249	Miscellaneous wood products	-.4	1.7	2.1	.2	1.5	2.9
251	Household furniture	.6	.7	.2	-1.4	.5	.9
252	Office furniture	-.7	-.6	.2	-1.3	2.1	.4
253	Public building and related furniture	.2	11.8	11.6	4.6	5.1	14.2
254	Partitions and fixtures	-.4	1.4	1.8	1.7	2.1	1.9
259	Miscellaneous furniture and fixtures	-.4	1.7	2.1	.3	2.3	2.9
262	Paper mills	-1.1	.4	1.5	-.8	2.9	1.8
263	Paperboard mills	-1.0	1.2	2.2	-.7	2.9	2.6
265	Paperboard containers and boxes	-.1	1.6	1.7	1.0	1.4	2.0
267	Miscellaneous converted paper products	.0	1.8	1.8	.4	2.2	2.0
271	Newspapers	-3.5	-3.5	.0	-.7	1.4	-.4
275	Commercial printing	.0	1.9	1.8	1.0	4.1	1.7
276	Manifold business forms	-3.0	-4.4	-1.4	-1.3	.0	-1.9
277	Greeting cards	-2.6	.9	3.6	2.0	1.6	6.1
278	Blankbooks and bookbinding	-.8	.8	1.7	-.7	2.3	3.6
279	Printing trade services	1.6	1.3	-.3	-1.3	2.6	-.8
281	Industrial inorganic chemicals	.0	.7	.7	-.3	-1.4	1.7
282	Plastics materials and synthetics	.3	2.1	1.8	-.4	2.9	2.0
283	Drugs	-2.1	3.4	5.7	2.1	6.4	6.5
285	Paints and allied products	-.9	.6	1.5	-1.9	.6	2.6
286	Industrial organic chemicals	-2.4	-.4	2.1	-.3	3.3	2.1
287	Agricultural chemicals	.4	1.7	1.3	.6	-.8	2.4
289	Miscellaneous chemical products	-.8	.9	1.8	-.1	2.0	2.3
291	Petroleum refining	.8	1.3	.6	-2.5	1.4	.6
295	Asphalt paving and roofing materials	.5	1.7	1.2	.3	1.5	1.2
299	Miscellaneous petroleum and coal products	-1.5	.5	2.0	2.0	1.2	2.1
301	Tires and inner tubes	2.1	2.8	.6	-.9	-.5	1.8
305	Hose and belting and gaskets and packing	.2	3.3	3.1	2.5	-.3	4.4
306	Fabricated rubber products, n.e.c.	1.4	2.9	1.5	.7	1.3	2.0

See footnote at end of table.

Table 1. **Multifactor productivity and related variables, average annual percent change, 1987-96—Continued**

SIC code	Industry	Multifactor productivity	Output	Combined inputs	Labor	Capital	Intermediate purchases
308	Miscellaneous plastics products, n.e.c.	.5	4.8	4.2	2.3	4.7	5.0
314	Footwear, except rubber	-.3	-4.6	-4.3	-7.0	-2.8	-3.4
321	Flat glass	1.8	.8	-1.0	.6	-.8	-1.9
322	Glass and glassware, pressed or blown	1.5	.4	-1.0	-1.7	-.2	-1.1
323	Products of purchased glass	1.1	4.4	3.2	2.1	3.7	3.6
324	Cement, hydraulic	2.4	1.4	-1.0	-1.4	-3.0	.4
325	Structural clay products	1.4	.5	-.9	-1.5	-1.2	-.4
326	Pottery and related products	1.0	2.9	1.9	.9	.6	3.7
327	Concrete, gypsum, and plaster products	.8	1.0	.2	.2	-1.4	.5
329	Miscellaneous nonmetallic mineral products	1.1	1.3	.2	.2	-1.0	.8
331	Blast furnace and basic steel products	1.1	3.2	2.1	-1.1	-1.5	4.9
333	Primary nonferrous metals	-1.7	1.0	2.7	-.2	-.2	4.0
335	Nonferrous rolling and drawing	-.6	-.1	.6	-.5	.7	.9
336	Nonferrous foundries (castings)	1.2	3.0	1.7	.7	1.6	2.4
339	Miscellaneous primary metal products	1.6	6.1	4.4	1.5	.5	7.7
341	Metal cans and shipping containers	2.4	.7	-1.7	-4.1	.5	-1.5
342	Cutlery, handtools, and hardware	-.4	1.2	1.6	-.7	.9	3.2
343	Plumbing and heating, except electric	.5	1.2	.7	-.7	.4	1.5
344	Fabricated structural metal products	-.1	1.5	1.6	.8	.5	2.2
347	Metal services, n.e.c.	1.1	4.8	3.7	1.9	3.1	5.0
348	Ordnance and accessories, n.e.c.	-1.8	-6.6	-4.8	-5.2	-1.2	-6.4
349	Miscellaneous fabricated metal products	-.1	2.7	2.8	1.8	1.7	3.6
351	Engines and turbines	.3	2.6	2.4	-.9	2.1	3.7
352	Farm and garden machinery	.5	4.3	3.7	.7	.6	5.6
353	Construction and related machinery	.8	3.8	3.0	1.4	-.1	4.1
354	Metalworking machinery	.6	3.0	2.4	1.4	1.0	3.6
355	Special industry machinery	.9	5.2	4.3	1.9	2.8	6.0
356	General industrial machinery	-.3	2.6	2.9	1.6	1.3	4.3
357	Computer and office equipment	14.4	20.4	5.3	-2.7	5.7	8.2
358	Refrigeration and service machinery	.2	3.6	3.3	2.0	2.1	4.3
359	Industrial machinery, n.e.c.	2.4	5.7	3.3	1.7	2.2	5.2
361	Electric distribution equipment	1.7	1.7	.1	-2.3	.0	1.3
362	Electrical industrial apparatus	1.4	3.5	2.1	-1.3	.7	4.6
363	Household appliances	.8	1.6	.8	-1.1	.3	1.4
364	Electric lighting and wiring equipment	.3	1.1	.8	-.7	.6	1.6
366	Communications equipment	2.3	7.2	4.8	-.2	4.0	8.3
367	Electronic components and accessories	14.8	20.3	4.8	.3	8.1	6.2
369	Miscellaneous electrical equipment and supplies	1.2	1.5	.3	-.8	2.7	.4
371	Motor vehicles and equipment	-.9	2.6	3.6	1.8	1.9	4.3
372	Aircraft and parts	.0	-2.9	-2.9	-4.2	2.4	-3.1
373	Ship and boat building and repairing	-1.3	-1.6	-.4	-1.5	-.9	.5
375	Motorcycles, bicycles, and parts	1.8	9.7	7.7	7.0	2.3	8.5
376	Guided missiles, space vehicles, parts	-1.9	-6.1	-4.2	-8.7	-.9	-2.1
381	Search and navigation equipment	.8	-4.1	-4.9	-7.7	-1.4	-3.3
382	Measuring and controlling devices	.6	4.2	3.5	-.4	3.9	6.5
384	Medical instruments and supplies	.7	6.3	5.6	2.4	6.7	6.9
385	Ophthalmic goods	3.2	6.7	3.4	-.5	6.8	5.3
386	Photographic equipment and supplies	.5	.2	-.3	-2.6	1.0	-1.0
391	Jewelry, silverware, and plated ware	-.7	-.5	.2	-.7	-.5	.8
393	Musical instruments	-1.6	-.4	1.3	2.3	-1.2	1.5
394	Toys and sporting goods	.6	4.0	3.4	1.9	1.6	4.3
395	Pens, pencils, office, and art supplies	3.1	3.4	.4	-.7	1.4	.4
399	Miscellaneous manufactures	1.2	2.5	1.3	1.2	2.0	1.4

n.e.c. = not elsewhere classified.