Multifactor productivity in the metal stampings industry

On average, multifactor productivity showed no growth over the 1963–91 period; a 0.9-percent average gain in labor productivity was due entirely to increases in capital and intermediate purchases relative to labor

Paul V. Kern
and
Thomas M. Muth II

Multifactor productivity, a measure relating output to the combined inputs of labor, capital, and intermediate purchases, remained constant, on average, between 1963 and 1991 in the metal stampings industry.[1] (See chart 1.) Many factors, such as new technology, changes in the skills and effort of the work force, and economies of scale, influence trends in multifactor productivity.

Since 1985, the Bureau of Labor Statistics has published a labor productivity measure for the metal stampings industry.[2] This article extends the Bureau's work by presenting a multifactor productivity measure for the industry.

Labor productivity in the metal stampings industry grew at an average annual rate of 0.9 percent over the 1963–91 period.[3] As measured by output per employee hour, labor productivity comprises the effects of changes in capital per hour, intermediate purchases per hour (materials, fuels, electricity, and purchased business services), and multifactor productivity. The multifactor measure accounts for the influences of the capital and intermediate purchases in the input measure and does not reflect the impact of these influences on the productivity residual. It also allows analysts to quantify the effects on labor productivity of changes in capital relative to labor and of intermediate purchases relative to labor.

The Bureau first published multifactor productivity measures in 1983, covering the private business sector, the private nonfarm business sector, and the total manufacturing sector. Since then, the Bureau has developed and published data for 20 two-digit manufacturing industries and 9 three-digit industries, including metal stampings.

Establishments in the metal stampings industry produce automotive stampings, stampings used primarily by other durable goods manufacturers, and crowns and closures used by producers of nondurable goods such as beverages and preserved fruits and vegetables. Manufacturers of automotive stampings accounted for more than 57 percent of the metal stampings industry's output in 1991. Metal stampings, not elsewhere classified (n.e.c.) made up 40 percent of output, while crowns and closures accounted for 3 percent.

The influence on output per hour of capital relative to labor is referred to as the *capital effect* and is measured by the change in the ratio of capital to labor, multiplied by the share of costs for capital in the total cost of producing output. The influence of intermediate purchases relative to labor is referred to as the *intermediate purchases effect* and is measured by the change in the ratio of intermediate purchases to labor, multiplied by the share of costs for intermediate purchases in the total cost of output.

Of the 0.9-percent average gain in output per hour over the 1963–91 period, the capital effect accounted for 0.2 percent, and the intermediate purchases effect accounted for 0.7 percent. (See table 1.) On average, multifactor productivity ac-

Paul V. Kern is an economist in the Office of Productivity and Technology, Bureau of Labor Statistics. Thomas M. Muth II is an economist formerly in the same office.

counted for none of the growth in output per hour, as both output and combined inputs increased 1.1 percent per year.

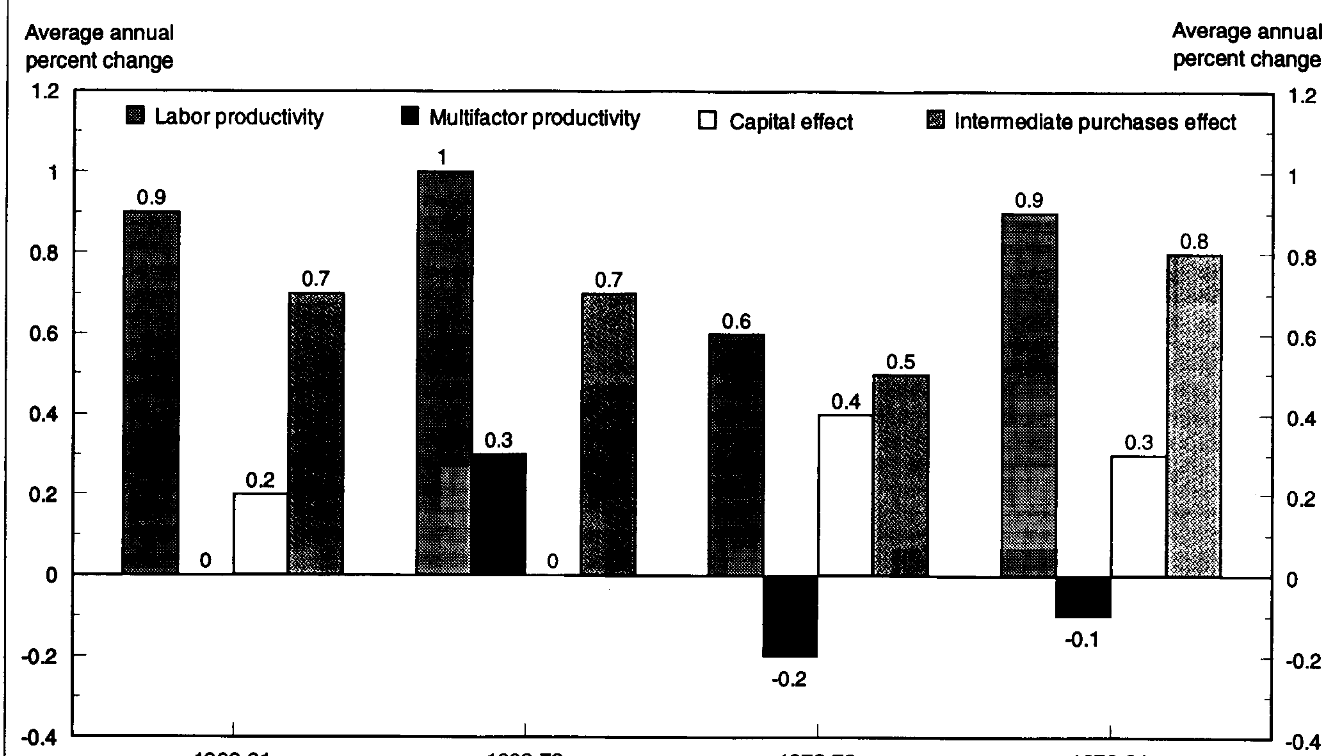
Growth in average annual output per hour slowed from 1.0 percent for the years 1963–73 to 0.6 percent from 1973 to 1979, but then rebounded to 0.9 percent per year over the 1979–91 period. (See table 2.) Output increased an average of 3.9 percent over the 1963–73 period and then fell 0.1 percent per year from 1973 to 1979. The average annual decline in output accelerated to 0.6 percent over the remainder of the period examined. The labor input growth rate fell from 2.8 percent for the years 1963–73 to an average annual decline of 0.7 percent over the 1973–79 period and then to a decline of 1.5 percent per year from 1979–91.

Increased growth in the capital effect tempered the 1973–79 slowdown in the labor productivity growth rate. Multifactor productivity remained constant, on average, over the 1963–91 period. After growing an average of 0.3 percent per year from 1963 to 1973, multifactor productivity contracted 0.2 percent per year over the 1973–79 period. Then, from 1979 to 1991, the average multifactor productivity decline slowed to 0.1 percent. The capital effect averaged zero growth over the 1963–73 period, but increased at an average annual rate of 0.4 percent from 1973 to 1979 and 0.3 percent over the 1979–91 period. The growth rate of the intermediate purchases effect fell from 0.7 percent over the 1963–73 period to 0.5 percent from 1973 to 1979 and then rose to 0.8 percent for the remainder of the period studied.

Changes in multifactor productivity reflect changes in output and the combined inputs of labor, capital, and intermediate purchases. (See tables 3 and 4.) As previously mentioned, output grew at an annual average rate of 3.9 percent over the 1963–73 period and then fell at annual rates of 0.1 percent over the 1973–79 and 0.6 percent over the 1979–91 periods. Average growth in combined inputs slowed from 3.6 percent over the 1963–73 period to 0.2 percent from 1973 to 1979. Combined inputs then declined at a rate of 0.5 percent per year over the 1979–91 period.

The changes in combined inputs mask somewhat divergent trends in the individual inputs of labor, capital, and intermediate purchases. Over the entire 1963–91 period, capital grew an average 2.5 percent, while labor averaged 0.2-percent growth and intermediate purchases posted a 1.5-percent average increase. As mentioned, labor hours declined at averages of 0.7 percent over the 1973–79 period and 1.5 percent from 1979 to 1991, after having grown 2.8 percent per year over the 1963–73 period. Subsequent to growing 4.3 percent annually, on average, during 1963–73, intermediate purchases slowed to 0.1-percent annual growth from

Chart 1 **The relationship of multifactor productivity to labor productivity in the metal stampings industry**



NOTE: Labor productivity equals multifactor productivity plus the effects of capital and intermediate purchases.

1973 to 1979. Intermediate purchases then fell an average of 0.2 percent per year over the 1979–91 period. Average annual growth of capital input slowed from 3.2 percent for the 1963–73 period to 2.0 percent from 1973 to 1979, before accelerating slightly to 2.2 percent over the remainder of the period studied.

The capital effect (the weighted change in the ratio of capital to labor) reflects differential movements in capital services, labor, and the capital share weight. As a result of the aforementioned trends in the growth of the capital and labor inputs, annual growth in the ratio of capital to labor surged from an average of 0.4 percent from 1963 to 1973 to 2.7 percent for the years 1973–79 and then accelerated further to 3.8 percent per year through 1991. The average share of capital fell from 15 percent over the 1963–73 period to 14 percent during 1973–79 and 8 percent from 1979 to 1991. These influences combined to yield a constant capital effect, on average, over the 1963–73 period and average yearly gains of 0.4 percent during 1973–79 and 0.3 percent over the 1979–91 period.

The intermediate purchases effect (the weighted change in the ratio of intermediate purchases to labor) can be decomposed in a similar fashion. Intermediate purchases grew 4.3 percent annually, on average, during the 1963–73 period and then slowed to 0.1-percent growth from 1973 to 1979. For the remainder of the period examined, intermediate purchases contracted 0.2 percent per year. These growth rates exceeded those of labor input in each period, although the rates converged somewhat over the 1973–79 period. As a result, the ratio of intermediate purchases to labor, which grew 1.5 percent from 1963 to 1973, increased just 0.8 percent over the 1973–79 period. The growth rate then rebounded to 1.3 percent during 1979–91. Intermediate purchases' average share of total cost climbed from 52 percent during 1963–73 to 54 percent over the 1973–79 period and 59 percent from 1979 to 1991. As a result of these trends, growth in the intermediate purchases effect, 0.7 percent over the 1963–73 period, was 0.5 percent from 1973 to 1979 and 0.8 percent over the 1979–91 period.

Table 1. **Average annual rates of growth in output per hour, multifactor productivity, and related measures, metal stampings industry, 1963–91**[1]

Measure	1963–91	1963–73	1973–79	Change, 1963–73 to 1973–79	1979–91	Change, 1973–79 to 1979–91
Output per hour	0.9	1.0	0.6	–0.4	0.9	0.3
Equals						
Multifactor productivity	.0	.3	–.2	–.5	–.1	.1
Plus						
The capital effect[2]	.2	.0	.4	.4	.3	–.1
Plus						
The intermediate purchases effect[3]	.7	.7	.5	–.2	.8	.3

[1] Each measure presented in this table is computed independently. Therefore, multifactor productivity, the capital effect, and the intermediate purchases effect may not sum exactly to output per hour, due to rounding.

[2] The capital effect is the change in the ratio of capital to labor, multiplied by the share of costs for capital in the total cost of output.

[3] The intermediate purchases effect is the change in the ratio of intermediate purchases to labor, multiplied by the share of costs for intermediate purchases in the total cost of output.

Output

Output in the metal stampings industry rose an average of 1.1 percent per year over the 1963–91 period. After posting relatively strong gains averaging 3.9 percent per year in the 1963–73 period, metal stampings output fell 0.1 percent per year from 1973 to 1979. After 1979, output fell further, an average annual rate of 0.6 percent. In the private nonfarm business sector, average annual output growth fell from 4.8 percent over the 1963–73 period to 2.9 percent during 1973–79, before slowing further to 2.3 percent from 1979 to 1991.

Output of the metal stampings industry is used primarily as intermediate goods by other manufacturing industries, mainly durable goods manufacturers. Therefore, demand for, together with the corresponding production of, other durables determines the major part of demand for metal stampings. Metal stampings production is highly cyclical and more volatile than production in either the total manufacturing or the durables manufacturing sector. Especially after 1973, strong upswings in industry output growth were followed by sharp declines as great as 18 percent.

Domestic motor vehicle and equipment production determines the greatest share of demand for the automotive stampings component of the metal stampings industry. The outputs of a variety of other durable manufacturing industries influence demand for output of the metal stampings, n.e.c. industry. These industries include the heating and plumbing equipment, fabricated structural metal, service industry machines, engines and turbines, and electronic components and equipment industries. In contrast to the other two components, the crowns and closures industry primarily manufactures intermediate goods for such nondurable goods manufacturers as the malt beverages and preserved fruits and vegetables industries.[4]

Detailed data concerning the three components of the metal stampings industry are not available separately for years prior to 1972. Since 1972, these components have shown divergent trends in output. Automotive stampings output grew an average of 0.5 percent for the years 1972–91. From 1972 to 1979, output growth averaged 0.3 percent; it then rose to 0.5 percent annually during 1979–91. Output in the automotive stampings component takes the form of fenders, trim, body panels, mufflers, hubcaps, and other automobile parts, all intermediate goods in the motor vehicle and equipment industry. The relationship between the automotive stampings component to the motor vehicle and equipment industry determines the cyclical nature of the output of the component.

For most of the period examined, trends in motor vehicle output strongly influenced changes in automotive stampings, although motor vehicle output grew at a faster average rate. The 3.0-percent difference in average growth rates between the two industries for the years 1972 to 1979 reflected a change in the intermediate goods structure of motor vehicle production. To meet Federal guidelines pertaining to fuel efficiency, automotive manufacturers adopted new applications for lighter weight materials. From 1975 to 1991, the volume of plastic used in the construction of the typical midsize domestic automobile grew 52 percent, while the amount of iron, steel, and aluminum fell 24 percent. New applications of plastics included body panels, front and rear bumper panels, bucket seats, fender extensions, and headlight housings.[5] Many of these applications displaced metal stampings. Over the 1973–78 period, motor vehicle and equipment output increased 18 percent, while the constant-dollar value of metal stampings consumed by the industry fell 14 percent.[6]

Output in the metal stampings, n.e.c. component remained constant, on average, from 1972 to 1991. Output grew 3.3 percent during the 1972–79 period, but then declined 1.8 percent annually from 1979 to 1991. The vast majority of output from this component serves as an intermediate good for other durable goods manufacturing industries. In 1982, 77 percent of the domestic consumption of metal stampings, n.e.c. commodities served as intermediate inputs for other hard-goods manufacturers.[7]

On average, output in the crowns and closures component fell 3.2 percent per year from 1972 to 1991, 1.1 percent for the years 1972–79, and 4.3 percent from 1979 to 1991. Crowns and closures output serves primarily as an intermediate good for such nondurable goods manufacturing industries as bottled and canned soft drinks; malt beverages; canned fruits and vegetables; and drugs, cleaning, and toilet preparations.[8] Many of these industries were growing over the period studied, but were shifting to the use of plastic-based products. From 1972 to 1991, shipments of metal commercial closures declined a total of 20 percent, while those of plastic closures grew 270 percent.[9]

Labor

In 1991, the metal stampings industry employed about 198,400 workers. The number of employees was 238,900 in 1969. Employment then fell to 198,200 in 1975, but rose to 250,200 employees in 1978. After 1978, employment fell each of the next four years, but then rebounded and settled at close to the 1975 level in 1991. Although nonproduction workers comprised just 18 percent of the industry's work force in 1963, the growth in their employment accounted for 56 percent of the net increase in total employment in the industry from 1963 to 1991. Also, the year-to-year changes in the number of nonproduction workers were not nearly as great as those for the more cyclically dependent production workers.

All employee hours grew 0.2 percent annually, on average, from 1963 to 1991. During the 1963–73 period, all employee hours grew at a rate of 2.8 percent per year; then, all employee hours declined at an annual rate of 0.7 percent during 1973–79 and 1.5 percent from 1979 to 1991. Production worker hours increased an average of 0.1 percent from 1963 to 1991, divided into a 2.9-percent annual average growth for 1963–73 and declines of 0.8 percent during 1973–79

Table 2. Average annual rates of growth in output per hour, output, hours, capital, intermediate purchases, and related measures, metal stampings industry, 1963–91

Measure	1963–91	1963–73	1973–79	Change, 1963–73 to 1973–79	1979–91	Change, 1973–79 to 1979–91
Output per hour	0.9	1.0	0.6	–0.4	0.9	0.3
Output	1.1	3.9	–.1	–4.0	–.6	–.5
Hours	.2	2.8	–.7	–3.5	–1.5	–.8
Capital	2.5	3.2	2.0	–1.2	2.2	.2
Capital per hour	2.3	4	2.7	2.3	3.8	1.1
Capital effect[1]	.2	.0	.4	.4	.3	–.1
Intermediate purchases	1.5	4.3	.1	–4.2	–.2	–.3
Intermediate purchases per hour	1.3	1.5	.8	–.7	1.3	.5
Intermediate purchases effect[2]	.7	.7	.5	–.2	.8	.3

[1]Capital per hour multiplied by the share of costs for capital in the total cost of output.

[2]Intermediate purchases per hour multiplied by the share of costs for intermediate purchases in the total cost of output.

and 1.8 percent during 1979–91. Nonproduction worker hours increased 0.8 percent per year over the 1963–91 period, growing at 2.5 percent per year, on average, from 1963 to 1973 and then trailing off to a constant level of input, on average, from 1973 to 1979. Nonproduction worker hours fell 0.1 percent annually from 1979 to 1991.

Annual growth in all employee hours and production worker hours was cyclical, following changes in output with virtually no lags. Because of firms' requirements for certain nonproduction services regardless of incremental changes in output, nonproduction labor grew in a less cyclical manner than total labor and, when it followed changes in output, demonstrated significant lags.

Average hourly earnings of production workers in the metal stampings industry was $12.98 in 1991, 16 percent higher than those of the manufacturing sector as a whole.[10] From 1972, the earliest year for which these data are available for metal stampings, to 1991, average hourly earnings rose at a rate of 5.5 percent per year, nearly the same rate of increase as the manufacturing sector sustained.

Capital

Capital input in the metal stampings industry comprises the flow of services derived from the equipment employed in the production of metal stampings; structures (mostly buildings housing the equipment used in production); finished goods, work in progress, and inventories of materials and supplies kept on hand in the firm; and the land on which the firm is located. Capital input in the industry increased an average of 2.5 percent from 1963 to 1991. From 1963 to 1973, output grew at a higher rate than capital—3.9 percent, compared with 3.2 percent. Over the next two subperiods studied, the opposite occurred: capital grew 2.0 percent, on average, while output fell 0.1 percent, for the years 1973–79, and capital increased 2.2 percent, whereas output declined 0.6 percent annually, from 1979 to 1991. Output per unit of capital input—that is, capital productivity—declined an average of 1.4 percent from 1963 to 1991. Capital productivity grew an average of 0.7 percent annually for the years 1963–73, but then declined 2.1 percent during 1973–79 and 2.7 percent over the 1979–91 period. The decline in capital productivity reflects the relatively steady growth in capital input over a period when output growth slowed.

Equipment accounted for about 50 percent of capital, on average, for the 1963–91 period. Structures made up an average of 21 percent of capital over the period, while inventories accounted for 23 percent and land 5 percent of capital. The proportions changed significantly over the period. Equipment's share rose from less than 50 percent in 1963 to more than 60 percent by the end of the period studied. Structures' share fell from about 28 percent at the beginning of the period to about 15 percent at the end. The share held by inventories rose from 18 percent in the beginning to more than 25 percent in the late 1960's and 1970's, but fell to 17 percent at the end of the period. Land's share fell from about 7 percent at the beginning of the period to about 4 percent at the end.

Intermediate purchases

Intermediate purchases input increased 1.5 percent per year, on average, over the period examined. From 1963 to 1973, intermediate purchases grew 4.3 percent annually. Growth then slowed to an average of 0.1 percent for the years 1973–79, before falling 0.2 percent from 1979 to 1991. Output per unit of intermediate purchases—that is, intermediate purchases productivity—declined an average of 0.4 percent over the period studied.

Table 3. Output and input indexes, metal stampings industry, 1963–91

(1987 = 100)

Year	Output	Combined inputs	Hours	Captial	Intermediate purchases
1963	64.0	65.0	83.7	53.7	57.9
1964	64.8	69.5	88.8	55.3	62.8
1965	74.6	77.6	96.8	59.2	72.3
1966	77.4	82.1	103.0	63.0	76.0
1967	74.8	79.2	100.4	65.6	71.3
1968	83.8	84.9	106.4	67.3	78.0
1969	83.0	86.1	108.0	69.5	78.6
1970	71.8	76.9	96.7	70.8	67.9
1971	76.0	77.6	92.4	70.8	71.1
1972	85.1	84.9	99.9	70.7	80.4
1973	93.6	92.7	110.4	73.6	88.2
1974	83.7	84.3	100.5	76.4	77.3
1975	68.6	74.8	84.3	76.0	68.7
1976	83.5	86.4	98.3	76.1	82.0
1977	94.8	94.9	108.6	78.9	91.0
1978	97.2	96.9	110.0	81.5	93.2
1979	93.1	93.5	105.9	83.0	88.9
1980	78.2	80.7	92.9	83.7	73.5
1981	78.2	79.9	91.6	85.8	72.5
1982	70.4	74.3	84.4	87.0	66.8
1983	83.9	83.1	92.2	85.9	77.3
1984	98.9	95.6	102.7	86.2	93.0
1985	96.8	98.2	105.4	88.6	95.5
1986	95.5	98.2	99.8	93.5	97.8
1987	100.0	100.0	100.0	100.0	100.0
1988	102.1	99.7	100.4	104.6	98.7
1989	99.1	97.9	98.3	106.2	96.8
1990	91.9	93.4	94.6	107.6	91.5
1991	86.8	88.4	88.2	108.0	87.0
Average annual percent change					
1963–91	1.1	1.1	.2	2.5	1.5
1963–73	3.9	3.6	2.8	3.2	4.3
1973–79	–.1	.1	–.7	2.0	.1
1979–91	–.6	–.5	–1.5	2.2	–.2

Intermediate purchases consist of materials, fuels, electricity, and purchased services used in the production process. Materials—in particular, metals—account for about 91 percent of the value of intermediate purchases in the metal stampings industry. Carbon steel, aluminum, and stainless steel made up the largest categories of materials inputs throughout the period examined. Purchases of carbon steel accounted for 41 percent of the total value of materials in 1963 and 59 percent in 1972, falling to 53 percent in 1987. Purchases of aluminum alloys made up 4 percent of the total value of materials in 1987, below their 9-percent share held in 1963. The share of stainless steel in the metal stampings materials purchases fell from 6 percent in 1963 to 3 percent in 1987.[11]

Total energy input—of electricity and fuels—constituted, on average, 2.5 percent of the value of intermediate purchases input in the metal stampings industry. Energy input increased 1.8 percent per year from 1963 to 1991. Energy grew 5.3 percent, on average, over the 1963–73 period, but then declined 1.2 percent from 1973 to 1979. Over the 1979–91 period, energy input grew 0.4 percent annually. The quantity of electricity purchased increased an average of 3.2 percent per year from 1963 to 1991. During 1963–73, electricity grew 8.3 percent per year. It then fell 0.3 percent annually from 1973 to 1979 and grew 0.8 percent per year for the remainder of the period studied. Fuels input declined an average of 0.8 percent yearly from 1963 to 1991. After showing no growth, on average, from 1963 to 1973, fuels input declined 2.9 percent annually over the 1973–79 period and 0.4 percent per year from 1979 to 1991.

Over the majority of the period studied, energy consumption—especially fuel—reacted to price changes nearly as strongly as to changes in output level of the metal stampings industry. As often as not, when fuel prices and output exerted conflicting influences, the change in fuel prices proved the stronger influence. From 1963 to 1991, output increased 1.1 percent annually. However, purchases of fuel declined 0.8 percent per year as fuel prices rose an average of 8.4 percent. In comparison to fuels, electricity input proved more responsive to changes in the output level.

Technological change

The metal stampings industry manufactures a wide range of components used in the production of capital goods and consumer durables. The parts produced—stampings—range in size from miniature electronic components to heavily ribbed boxcar ends and range in complexity from flat washers to deeply drawn automotive parts.[12] Technological change in the industry has sprung from unusual sources, such as a weapons laboratory in California, and from simple refinement and diffusion of technology developed prior to the period studied.

The principal tool employed in producing metal stampings is the production press. Production presses close a slide to a bed or anvil in a controlled reciprocating motion along a defined path.[13] In closing one or more dies to a desired position with the proper force, presses shear, pierce, bend, and otherwise distort the workpiece, converting it into the desired size and shape.[14] Presses have become faster, more powerful, more accurate, and more flexible. Press capacity over the 1966–76 period was 4 times greater, on average, than it was over the preceding 35 years, and stroke speeds of large transfer presses were 4 to 5 times faster than they were 30 years prior to the same period.[15] Operating speeds of some presses reach as high as 2,000 strokes per minute. Such high rates require all related activities to be automatic.[16] Presses that are currently available have the capacity to hold tolerances low without sacrificing operating speed. A 60-ton pro-

Table 4. Multifactor and related productivity indexes, metal stampings industry, 1963–91

[1987 = 100]

Year	Multifactor productivity	Output per hour	Output per unit of capital	Output per unit of intermediate purchases
1963	98.5	76.5	119.2	110.5
1964	93.2	73.0	117.2	103.2
1965	96.1	77.1	126.0	103.2
1966	94.3	75.1	122.9	101.8
1967	94.4	74.5	114.0	104.9
1968	98.7	78.8	124.5	107.4
1969	96.4	76.9	119.4	105.6
1970	93.4	74.3	101.4	105.7
1971	97.9	82.3	107.3	106.9
1972	100.2	85.2	120.4	105.8
1973	101.0	84.8	127.2	106.1
1974	99.3	83.3	109.6	108.3
1975	91.7	81.4	90.3	99.9
1976	96.6	84.9	109.7	101.8
1977	99.9	87.3	120.2	104.2
1978	100.3	88.4	119.3	104.3
1979	99.6	87.9	112.2	104.7
1980	96.9	84.2	93.4	106.4
1981	97.9	85.4	91.1	107.9
1982	94.8	83.4	80.9	105.4
1983	101.0	91.0	97.7	108.5
1984	103.5	96.3	114.7	106.3
1985	98.6	91.8	109.3	101.4
1986	97.3	95.7	102.1	97.6
1987	100.0	100.0	100.0	100.0
1988	102.4	101.7	97.6	103.4
1989	101.2	100.8	93.3	102.4
1990	98.4	97.1	85.4	100.4
1991	98.2	98.4	80.4	99.8
Average annual percent change				
1963–91	.0	.9	–1.4	–.4
1963–73	.3	1.0	.7	–.4
1973–79	–.2	.6	–2.1	–.2
1979–91	–.1	.9	–2.7	–.4

gressive die press is reportedly capable of holding tolerances to 0.0005 inch at 1,600 strokes per minute.[17] In addition to increased power, speed, and accuracy, further diffusion of progressive die and transfer press technology has allowed for increased efficiency in operations requiring multiple press strokes.

In the progressive die, the workpiece is fed through a series of die stations within a master die on a single press. The part is usually formed from coil that is fed automatically through the press and normally is not sheared from the carrier ribbon until it reaches the final die station. Larger stampings, which cannot be transferred on a carrier ribbon, may require several hand-fed operations to form a single stamping.[18] In this case, the slowest operator performing the manually fed operations defines the operating speed. Transfer presses, which employ individual die stations within the master die and a transfer mechanism coupled to the press, do not face the same limitations on size and sequence as progressive dies do. Because they do not require a carrier ribbon, transfer presses are able to move large workpieces automatically between stamping stations. Elimination of the carrier ribbon has resulted in material savings estimated at 20 percent to 40 percent.[19] Progressive dies and transfer presses reduce labor requirements for the production of complex stampings and allow for increased speed, a higher level of consistency (quality), and an increased duration of operation in the stamping process.

One method of improving the productivity of a press line that cannot support progressive dies or transfer presses is to retrofit the line with robotic transfer equipment between presses, mimicking a transfer press. For jobs in which the use of a progressive die was judged not feasible, one firm employed robotic loading, transfer, and unloading equipment with a battery of six open-back, inclinable presses. The adoption of the equipment reduced the labor requirement for the operation by more than 50 percent.[20] Although the operating speed was not dramatically higher than that of manually fed operations, the line ran continuously through breaks, lunch hours, and changes in shift.

For simpler pressing and drawing operations, such as those involved in the production of cans slated to contain beverages, most of the effort of new technology is aimed at increasing speed. The largest manufacturer of metal cans, crowns, and aluminum and plastic closures is currently running plants with production lines that can stamp 1,650 cans per minute, but expects production lines capable of raising the figure to more than 3,000 cans per minute soon. At these speeds, computer monitoring of all operations is crucial. Should a press stroke fail to form a can as planned, material could pile up and destroy equipment. Programmable logic controllers are used by the company to monitor all operations. A total of 69 such devices, each with a minimum of 50 inputs and outputs, is needed in the manufacture of the company's cans. The units are able to communicate with each other, so any problems that arise can be quickly resolved by operators. This form of communication is not limited to just the plants themselves: the company's corporate headquarters is linked to the controllers so as to be able to obtain information on production, downtime, and can counts. Quality is still a concern at all stages of production. The firm uses a light tester that can find the smallest of holes in a less than perfect can, and those cans get blown off the line with a stream of pressurized air.[21]

In addition to increasing the efficiency of production runs, the metal stampings industry has devoted a great deal of attention to the relationship between productivity and flexibility. To make shorter production runs more feasible, firms have focused on reducing the time required to change dies and, as a result, increasing the operating time of presses. In place of manually bolting dies to the press bed, companies in the industry have used mechanical and hydraulic clamps to decrease the time required to change dies. Although incapable of exerting as much force as hydraulic clamps do, mechanical clamps are easier to retrofit the press for, are simpler to use, and are less costly than their hydraulic counterparts.[22] Some manufacturers who have not felt the need to invest in the new technology have been able to simplify and speed die changes through standardizing the height of the die.

Reducing the time taken to change dies has also involved the installation, removal, transport, and storage of the dies. New systems of die lifters, prerollers, bolsters, cranes, and die carts now make it possible for manufacturers to reduce the time taken to change a die from hours to minutes. As an example, a large automotive stamper that purchased a system of die carts and related equipment for six large-capacity presses reduced its changeover time from a full 8-hour shift to 45 minutes.[23]

Most dies used by the industry are one of two types: prototype dies or steel dies. A prototype die is made of zinc and is generally used to make a few hundred or few thousand parts to verify the shape of the die, and then a steel die must be produced that replicates the zinc die for the rest of a production run. Because it can take up to 10 weeks to make the prototype die and 24 weeks to make a steel die (for an automotive hood, for example), a significant reduction in cost and development time can be realized with a new product. GMR311 is a special zinc alloy with a surface hardness much greater than that of conventional zinc. It can be used to produce more than 40,000 parts before reworking the die is necessary. While this is a low figure compared to what high-volume steel dies produce, it is enough to fill many low-production orders for niche products. So instead of creating two dies for a limited production run, only the one GMR311 die is built. Parts stamped from the new dies include fender brackets and fenders, roofs for pickup trucks, fuel tanks, oil pans, and parts for convertibles.[24]

Many firms in the metal stampings industry opt to retain their considerable investment in older, possibly outdated equipment. Some smaller firms purchase used equipment from larger stampers that are in the process of modernizing their machine tools. In 1989, 35 percent of the metalforming machine tools and 29 percent of the metalcutting machine tools were more than 20 years old in the industry group that includes the metal stampings industry.[25] The percentage of metalforming equipment under 10 years old fell from 33 percent in 1968 to 20 percent in 1983 and then rose to 26 percent in 1989.[26] The penetration of numerical control was fairly limited; in 1983, 10 percent of firms in the industry had numerically controlled shearing and punching machines, and 4 percent had numerically controlled bending and forming machines.[27] Slightly more than 1 percent of metalforming machine tools were numerically controlled.[28]

Numerical control was first applied to a stamping press in the early 1950's.[29] Initial numerical control units read instructions from a computer-generated, perforated tape. As electronic devices became more compact and reliable, control units assumed data-processing functions, and the distinction between the computer and the control unit grew less pronounced.[30] Computerized numerical controls became widely available in the early 1970's. These controls allowed for the direct entry of specifications into the control unit. Some also had the capacity to interface with computers, allowing for the closer integration of the production process with computer-aided design. Currently, one of the more provocative applications of control technology in conventional presses is the flexible fabrication system. One system that is available is capable of stamping a variety of related parts in a single run without the need to change the die manually. All operations, from the unloading of coil on the uncoiler to the stacking of finished stampings, are automatic. The operator changes the specification of a part by directly entering responses to computer-generated prompts.[31] The change is almost instantaneous and makes shorter production runs more feasible.

Regardless of the type of control and die used to stamp a part, manufacturers will sometimes produce unsatisfactory products that will be rejected by the consumer—an auto plant, for example. A firm in Michigan that makes quarter panels and trunk lids for Ford's Lincoln Town Car tries to catch any malformed product before it leaves the shop. As many as 60 different points on one body panel are measured to ensure that the panel will fit properly on the automobile. The company uses voice recognition technology to enable its inspectors to carry out data collection in a manner in which the inspectors need not look at or touch the recording device. The device employed is portable, battery powered, and able to digitize the operator's speech. The results are uploaded to a minicomputer. Even in a noisy plant, only the operator's individual voice is recognized by the device, which alerts an inspector if a measurement is not within the range specified by engineers and tells the inspector where to take the next measurement. This allows each inspector to increase the number of panels examined per shift and to do so in a more accurate fashion, with less strain and stress on the operator. No longer do the inspectors have to write down their findings on paper and then enter them into a computer after each shift. The new process precludes manual data entry errors simply because there is no manual data entry.[32]

Another target of new technology in the industry is the design of the dies themselves. Dyna3D is a massive computer program (150,000 lines of code) developed at Lawrence Livermore National Laboratory to model and predict the effects of collisions and explosions. Originally a secret military project, it is now used by nearly every auto manufacturer and several firms that manufacture metal stampings. Dyna3D helped a brewer create a tougher beer can, and one of the largest aluminum stampings firms is using the program to model tools and dies used to make metal stampings. Conceptually, the software throws a mesh over any object, and when this mesh of elements is hit, with a missile or a stamping die, the stresses and strains on each unit of the mesh can be calculated. It is much cheaper to simulate the stamping of a large piece of metal with an experimental die than to construct a genuine die and use it to stamp an actual metal part, which may then be found unacceptable because the new die is not formed properly; also, the stamping process can be performed many times, under different conditions. This type of simulation software saves money in materials and can lead to new metal-stamped products.[33]

Technological advancements in the metal stampings industry are not as readily apparent as in other sectors of the economy. Nonetheless, significant progress has been made in the areas of speed, accuracy, cost reduction, and life span of the equipment itself. These advancements help reduce the production costs of many of the final products used by consumers every day, such as beverage cans, washers and dryers, and automobiles.

OUTPUT PER HOUR in the metal stampings industry increased at an average annual rate of 0.9 percent over the 1963–91 period. This growth rate can be decomposed into average growth rates of 0.2 percent in the capital effect and 0.7 percent in the intermediate purchases effect, while multifactor productivity exhibited no growth. The slowed average annual growth exhibited in labor productivity in the periods after 1973 reflect mild declines in multifactor productivity, partially offsetting modest growth in both the capital effect and intermediate purchases effect. Multifactor productivity grew somewhat in the 1963–73 period (0.3 percent per year, on average), but declined slightly in the 1973–79 and 1979–91 periods.

The decline in output growth is due in part to substitutions of other materials for metal-stamped products in the industries that were the largest consumers of stampings. Many of the technological advances in production presses, related equipment, and solid-state controls seem limited to a small number of firms, primarily the large automotive stamping firms and some of the large and midsize job shops. □

Footnotes

[1] As discussed in this article, the metal stampings industry is composed of three separate four-digit industries with standard industrial classification (SIC) codes 3465, 3466, and 3469. (See *Standard Industrial Classification Manual* Executive Office of the President, Office of Management and Budget, 1987), p. 191.

[2] See Horst Brand and Clyde Huffstutler, "Trends of labor productivity in metal stamping industries," *Monthly Labor Review*, May 1986, pp. 13–20.

[3] All average rates of change presented in this article are compound rates.

[4] *The Detailed Input-Output Structure of the U.S. Economy, 1982* (Department of Commerce, 1991), pp. 1–200.

[5] See the following articles by Al Wrigley in *Ward's Automotive Yearbook* (Detroit, Ward's Communications): "'Light' More 'Right' than Ever in Automotive Materials," 1975, p. 56; "Materials and Processes: Size, Weight Reductions Take Priority," 1977, pp. 71–73; and "1978: A Year of Material Breakthroughs and Weight Reductions," 1979, p. 75. See also Drew Winter, "Recycling a Top Issue; Steel Making Big Gains," *Ward's Automotive Yearbook*, 1992, p. 36.

[6] *Studies in the Economics of Production: The U.S. Motor Vehicle and Equipment Industry since 1958* (Department of Commerce, 1985), p. 107.

[7] *The 1982 Benchmark Input-Output Accounts of the United States* (Department of Commerce, 1991), pp. 110–11.

[8] *Structure of the U.S. Economy, 1982*, pp. 1–200.

[9] *Current Industrial Reports: Closures for Containers, Summary for 1972* (Department of Commerce, 1975), pp. 2–3. See also the 1991 summary (1992), pp. 1–3.

[10] Average hourly earnings of production workers in the metal stampings industry are not available prior to 1972. From 1972 to the present, average hourly earnings are reported for SIC's 3465 and 3469 only. The average wage in the industry was computed as an average of average hourly earnings of production workers for SIC's 3465 and 3469, weighted by annual hours of production workers.

[11] *1972 Census of Manufactures*, vol. II, part 2 (Department of Commerce, August 1976). See also the 1987 *Census*, vol. II, part 2 (April 1990).

[12] Frank H. Habricht, *Modern Machine Tools* (Princeton, NJ, Van Nostrand, 1963), p. 197. See also Charles Wick, John T. Benedict, and Raymond F. Veilleux, eds., *Tool and Manufacturing Engineers Handbook*, vol. II, 4th ed. (Dearborn, MI,. Society of Manufacturing Engineers, 1984), p. 4–2.

[13] Frank W. Wilson, Philip D. Harvey, and Charles B. Gump, Jr., eds., *Die Design Handbook* (New York, McGraw-Hill, 1965), pp. 1–8.

[14] Habricht, *Modern Machine Tools*, p. 197.

[15] "The Machine Tools That Are Building America," *Iron Age*, Aug. 30, 1976, p. 269.

[16] Robert Rice, "Manufacturing with the Use of the Transfer Systems," *The Fabricator*, November 1979, p. 1.

[17] Leo R. Rakowski, "Press Advances Spur Stamping Productivity Gains," *Machine Tool Blue Book*, November 1979, p. 181.

[18] Rice, *Transfer Systems*, p. 2.

[19] *Ibid.*, p. 2.

[20] Dan Daniels, "How CMS Took the Pain Out of Second Operations," *Metal Stamping*, April 1986, p. 7.

[21] Conrad Casciato, "Crown Cork Keeps the Cans Coming," *Manufacturing Systems*, April 1993, pp. 50–52.

[22] John T. Winship, "A Broad Look at Quick Die Changing, Part 1," *Metal Stamping*, December 1987, p. 6.

[23] John T. Winship, "A Broad Look at Quick Die Changing, Part 2," *Metal Stamping*, January 1988, p. 18.

[24] Gary S. Vasilash, "Producing Stamping Tools in a Fraction of Time...," *Production*, February 1994, pp. 58–59.

[25] "14th American Machinist Inventory," *American Machinist*, November 1989, pp. 92–93.

[26] "American Machinist Tenth Inventory," *American Machinist*, November 1968, p. 89; "14th American Machinist Inventory," pp. 92–93.

[27] "14th American Machinist Inventory," pp. 92–93.

[28] "13th American Machinist Inventory," *American Machinist*, November 1983, p. 122.

[29] "Moving from Art to System," *American Machinist*, November 1977, p. G-14.

[30] "Machine Tools Building America," p. 291.

[31] "FFS Eliminates Manual Die Change (Iowa Precision Industries)," *Tooling and Production*, July 1983, p. 81.

[32] "Voice Recognition Aids Data Collection," *Quality*, October 1993, p. 60.

[33] Jeffrey Young, "Crashware," *Forbes*, Apr. 13, 1992, pp. 110–112.

APPENDIX: Measurement of multifactor productivity

Methodology and data definitions

The following is a brief summary of the methods and data that underlie the multifactor productivity measure for the metal stampings industry. A technical note containing more details is available from the authors at the Office of Productivity and Technology, Bureau of Labor Statistics, 2 Massachusetts Ave., N.E., Washington, DC 20212.

Output. The output measure for the metal stampings industry is based on the weighted change in the deflated value of shipments of various types of metal stampings, as reported in the *Census of Manufactures* and *Annual Survey of Manufactures*. Deflated five-digit primary product shipments were Tornqvist aggregated using the values of product shipments as weights. This measure is in turn benchmarked to Tornqvist indexes of constant-dollar production calculated from detailed quantity and value data published in the *Census of Manufactures* for 1963, 1967, 1972, 1977, 1982, and 1987.

For multifactor measures for individual industries, output is defined as total production, rather than the alternative of value added. For a value-added measure, intermediate inputs are subtracted from total production. Consequently, an important difference between the multifactor productivity indexes BLS publishes for individual industries and those for aggregate sectors of the economy is that the latter measures are constructed within a value-added framework. For the major sectors of the economy, intermediate transactions tend to cancel out; intermediate inputs are much more important in production at the industry level.

Further, output in the measures for individual industries is defined as total production that "leaves" an industry in a given year in the form of shipments, plus net changes in inventories of finished goods and work in process. Shipments to other establishments within the same industry are excluded when data permit, because they represent double counting, which distorts the productivity measures.

Labor. Employee hours indexes, which represent the labor input, measure the aggregate number of employee hours. These hours are the sum of production worker hours from the BLS establishment payroll surveys and nonproduction worker hours, derived by multiplying the number of nonproduction workers from BLS surveys of establishments in the industry by an estimate of average annual hours worked by nonproduction workers. The labor input data are the same as those used in the previously published BLS output-per-hour series for the metal stampings industry.

Capital. A broad definition of capital input, including equipment, structures, land, and inventories, is used to measure the flow of services derived from the stock of physical assets. Financial assets are not included.

For measurements of productivity, the appropriate concept of capital is *productive* capital stock, which represents the stock used to produce the capital services employed in current production. To measure the productive stock, it is necessary, for each type of asset, to take account of the loss of efficiency of the asset as it ages. That is, assets of different vintages have to be aggregated. For the measures in this article, a concave form of the age-efficiency pattern (efficiency declines more slowly during the earlier years) is chosen.

In combining the various types of capital stock, the weights applied are cost shares based on implicit rental prices of each type of asset. They reflect the implicit rate of return to capital, the rate of depreciation, capital gains, and taxes.[1]

Intermediate purchases. Intermediate purchases include materials, fuels, electricity, and purchased business services. Materials measured in real terms refer to items consumed or put into production during the year. Freight charges and other direct charges incurred by an establishment in acquiring these materials are also included. The data from which the intermediate inputs are derived include all purchased materials and fuels, regardless of whether they were purchased by the individual establishment from other companies, transferred to it from other establishments within the same company, or withdrawn from inventory during the year. An estimate of intraindustry transactions is removed from materials and fuels.

Annual estimates of the cost of services purchased from other business firms are also required for the measurement of multifactor productivity in a total output framework. Some examples of such services are legal services, communication services, and repair of machinery. An estimate of the constant-dollar cost of these services is included in the intermediate purchases input.

Cost shares for capital, labor, and intermediate purchases. Weights are needed to combine the indexes of the major inputs into a combined input measure. The weights for the metal stampings industry are derived by dividing an estimate of cost in current dollars for each input by the total cost of all inputs.

Conceptual framework

The multifactor productivity measure presented in this article is computed by dividing an index of output by an index of the combined inputs of capital, labor, and intermediate purchases. The framework for measurement is based on a production function that describes the relation of the output to the inputs and on a formula for an index that is consistent with this production function.

The general form of the production function underlying the multifactor productivity measures is postulated to be

$$Q(t) = Q(K(t),L(t),M(t),t) \tag{1}$$

where $Q(t)$ is total output, $K(t)$ is input of capital services, $L(t)$ is input of labor services, $M(t)$ is input of intermediate purchases, and t is time.

Differentiating equation (1) totally with respect to time, we obtain, after some algebraic manipulations, the sources-of-growth equation,

$$\frac{\dot{Q}}{Q} = \frac{\dot{A}}{A} + w_k\frac{\dot{K}}{K} + w_l\frac{\dot{L}}{L} + w_m\frac{\dot{M}}{M} \tag{2}$$

where $\dot{Q}/Q$ is the rate of change of total output, $\dot{A}/A$ is the rate of change of multifactor productivity, $\dot{K}/K$ is the rate of change of input of capital services, $\dot{L}/L$ is the rate of change of input of labor services, $\dot{M}/M$ is the rate of change of input of intermediate purchases, w_k is output elasticity (percent change in output due to a 1-percent change in input) with respect to the capital input, w_l is output elasticity with respect to the labor input, and w_m is output elasticity with respect to the intermediate purchases input. (A dot over a variable indicates the derivative of the variable with respect to time.)

Equation (2) shows the rate of change of output as the sum of the rate of change of multifactor productivity and a weighted average of rates of change of capital, labor, and intermediate purchases inputs. Now, if competitive output and input markets are assumed, then each input is paid the value of its marginal product. In that case, the output elasticities can be replaced by factor cost shares; that is,

$$w_k = \frac{P_kK}{P_qQ},\quad w_l = \frac{P_lL}{P_qQ},\quad w_m = \frac{P_mM}{P_aQ}$$

where P_q is the price of output and P_k, P_l, and P_m are the prices paid for the capital (K), labor (L), and intermediate purchases (M) inputs, respectively. Furthermore, if constant returns to scale are assumed, then $w_k + w_l + w_m = 1$.

Equation (2) can be rewritten as

$$\frac{\dot{A}}{A} = \frac{\dot{Q}}{Q} - w_k\frac{\dot{K}}{K} - w_l\frac{\dot{L}}{L} - w_m\frac{\dot{M}}{M} \tag{3}$$

In this expression, the growth of multifactor productivity can be seen as a measure of economic progress; it measures the increase in output over and above the gain due to increases in inputs.

Equation (2) can also be transformed into a contribution equation, which allows for an analysis of the change in output per hour. First, we subtract $\dot{L}/L$ from both sides of the equation. Then, because the weights sum to unity, we apply the term $(w_k + w_l + w_m)$ to the $\dot{L}/L$ term inserted on the right-hand side. Finally, we collect terms with the same weight, to obtain

$$(4) \qquad \frac{\dot{Q}}{Q}-\frac{\dot{L}}{L}=w_k\left[\frac{\dot{K}}{K}-\frac{\dot{L}}{L}\right]+w_m\left[\frac{\dot{M}}{M}-\frac{\dot{L}}{L}\right]+\frac{\dot{A}}{A}$$

The left side of equation (4) is the growth rate of output per hour. The terms in brackets are the rates of change in the ratios of capital to labor and intermediate purchases to labor. Thus, the rate of growth in output per hour can be decomposed into the weighted sums of changes in these ratios plus the change in multifactor productivity.

Equations (2), (3), and (4) describe aggregation in continuous form. The BLS multifactor indexes are constructed according to a Tornqvist formula that represents aggregation at discrete points in time and is consistent with a transcendental logarithmic production function. The rate of change in output or an input is calculated as the difference from one period to the next in the natural logarithms of the variables. For example, $\dot{Q}/Q$ is calculated as

$$\ln Q(t) - \ln Q(t-1).$$

Indexes are constructed from the antilogarithms of this differential. The weights w_k, w_l, and w_m are calculated as the arithmetic averages of the respective shares in periods t and $t-1$.

Footnote to the appendix

[1] For an extensive discussion of the measurement of capital, see *Trends in Multifactor Productivity, 1948–81*, Bulletin 2178 (Bureau of Labor Statistics, 1983).