Productivity in making air conditioners, refrigeration equipment, and furnaces

Output per hour rose rapidly during 1967–73, reflecting brisk demand; output tended to stagnate after 1973, but was shored up by orders for energy-efficient equipment and by export sales

HORST BRAND AND CLYDE HUFFSTUTLER

Output per employee hour in the manufacture of air conditioning, refrigeration, and warm-air heating equipment[1] rose at an average annual rate of 1.3 percent between 1967 and 1982, compared with 2.4 percent a year for all of manufacturing. Output climbed 3.4 percent a year during the period, and employee hours, 2.1 percent. (See table 1.) Strong expansion in the demand for the industry's residential, commercial, and industrial products, and rapid diffusion of basic improvements in metalworking technologies (such as numerical control and computer numerical control) were among factors underlying the rising productivity trend.

The improvement in the industry's productivity occurred mostly in the earlier part of the period reviewed. After 1973, output per employee hour did not change, as shown by the following tabulation of average annual rates of change:

	Industry	*All manufacturing*
1967–82	1.3	2.4
1967–73	5.1	3.4
1973–82	0.0	1.7

The industry's productivity rate for the 1967–73 period was 50 percent again as high as for manufacturing, but thereafter the trends in the two rates diverged.

Year-to-year swings in the industry's productivity were comparatively moderate. These swings ranged between a 9-percent increase in 1972 and a 16-percent decrease in 1975. Year-to-year increases in productivity outnumbered decreases by 12 to 2 (no change was recorded for 1973). In the years when productivity dropped, output dipped less than employee hours. Thus, in 1975 and 1980, productivity declined 16 percent and 7 percent while output dipped 34 percent and 16 percent, and employee hours, 22 percent and 10 percent. In 1974, productivity rose as a 6-percent decline in output was outdistanced by a 9-percent decline in employee hours.

Output and demand

The manufacture of air conditioning and refrigeration equipment and of warm-air furnaces involves the production of heat transfer apparatus for residential, commercial, and industrial applications, as well as for hospitals, marine vessels, freight and passenger vehicles, and many specialized applications. Heat transfer equipment here includes unitary air conditioners (units that operate on electric circuits of their own); room air conditioners; commercial refrigeration equipment (including frozen food display cases); as well as heat pumps and dehumidifiers. The industry, in addition, manufactures compressors and condensers, not only for its own final output, but also for home refrigerators (classified by the Bureau of the Census as a separate industry.)[2]

The industry's output rose at an average annual rate of 3.4 percent between 1967 and 1982. The rate for the earlier part of the period ran four times higher than that for all

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manufacturing, but dropped below the all-manufacturing rate during 1973–82:

	Industry	*All manufacturing*
1967–82	3.4	2.4
1967–73	12.3	3.2
1973–82	0.1	1.7

Among reasons underlying the industry's output growth, and underpinning it after 1973, have been exports. As a proportion of value of shipments, exports by the industry nearly doubled between the earlier and the later period studied here—from 8 percent to 14 percent (reaching 19 percent in 1982). For manufacturing as a whole, the export share in the value of shipments increased less markedly—from 6 percent in 1972 to 10 percent in 1980.

The much slowed expansion in the industry's output from 1973 forward corresponds to trends in the output of its major product groups, which in turn parallel the trends in underlying demand from the industry's most important markets.

Thus, the production of heat transfer equipment other than unitary or room air conditioners or warm-air furnaces increased at a rate nearly 10 times higher over the 1967–73 period than during the 1973–82 span. The increase in the rate had resulted largely from strong demand for motor vehicle air conditioners (which account for more than one-half of the products in the group). Such demand was associated with an increase in motor vehicle output of close to 6 percent a year in 1967–73. The subsequent tapering of output growth mirrored a falling-off in the annual rate of motor vehicle output by -1.0 percent for 1973–82.

Likewise, output rates of growth of unitary air conditioners and commercial refrigeration equipment slowed after 1973; for warm air furnaces, the rate declined. This pattern was linked largely to developments in construction (which accounts for well over one-third of the demand for the industry's products).[3] The average annual rate of change in the constant-dollar value of new residential housing construction, for example, declined from around 9 percent for 1967–73 to 2 percent thereafter; that for commercial structures, from 15 percent to 9 percent; and that for hospitals (public and private) turned from a 5-percent annual gain to a 4-percent annual decrease. Only industrial construction evidenced a contrary trend, with a 10-percent annual decline in the earlier period giving way to a 3.5-percent annual rise after 1973.

Leaving aside the medium-term swings, the industry's output has been sustained over the longer run by rapidly growing use of central and room air conditioning in homes, as well as more gradual increases in offices and other commercial space, hospitals, and probably in factories. Increases in the size of homes and other structures generated the shift in demand from room air conditioners to central systems and spurred the demand for warm-air furnaces, which function through the same air circulation system as central air conditioners. In the middle and late 1960's, 28 percent of all new homes were equipped with central air conditioners; that proportion rose to 43 percent between 1970 and 1975, and to 66 percent by 1982. Square footage per new home, to which the size of heat transfer equipment is linked, increased 9 percent between the mid-1960's and the early 1980's. The proportion of homes wired for room air conditioners more than doubled between the mid-1960's and the mid-1970's, to 53 percent, but it did not rise much thereafter. Warm-air ducted heating systems in occupied housing units rose by about one-third between 1970 and 1975, but by only 7 percent between 1975 and 1980.[4] For offices, shopping centers, and hospitals, pertinent data on air conditioning and forced warm-air systems are available only for some recent years. According to a survey conducted in the early 1970's, 91 percent of all commercial office buildings had central air conditioning, and 67 percent had forced-air heating systems. For shopping centers, the comparable figures were close to 100 percent in 1977; and for hospitals and nursing homes, they read 97 percent and 56 percent in 1975.[5] These data suggest that industry output is sustained not only by the net increase in such structures, but from replacement and retrofitting with more energy-efficient equipment as well. In 1981, for example, more than half of total residential expenditures on air conditioning and heating systems were for replacement.[6]

Furthermore, the introduction of more energy-efficient heat transfer equipment since about 1975 has also bolstered output. For the same wattage per hour of electric energy input, higher equipment output capacities, as measured in British Thermal Units (BTU's), have been achieved. Thus, in 1976, the Air Conditioning and Refrigeration Institute listed 56 percent of new unitary air conditioners as having

Table 1. Productivity and related indexes for the refrigeration and heating equipment industry, 1967–82

[1977 = 100]

Year	Output per employee hour	Output	All employee hours	Employees
1967	77.5	53.6	69.2	68.4
1968	82.3	60.8	73.9	73.1
1969	87.6	73.0	83.3	81.7
1970	88.4	73.7	83.4	83.8
1971	94.8	75.9	80.1	80.5
1972	103.0	99.0	96.1	93.5
1973	103.0	112.5	109.2	107.0
1974	106.9	105.9	99.1	99.2
1975	89.9	69.7	77.5	78.9
1976	94.1	87.5	93.0	91.6
1977	100.0	100.0	100.0	100.0
1978	100.6	110.8	110.1	107.6
1979	102.2	112.4	110.0	109.4
1980	95.0	94.0	98.9	99.4
1981	101.1	102.2	101.1	101.3
1982	101.3	90.3	89.1	90.3
	Average annual rates of change (in percent)			
1967–82	1.3	3.4	2.1	2.2
1977–82	([1])	−2.6	−2.6	−2.2

[1]Less than 0.05 percent.

energy efficiency ratios of between 6.5 and 7.4, and 18 percent with ratios of 7.5 to 8.4 (that is, their BTU output averaged that many times above their power input). By 1981, the proportion of the lower efficiency units had shrunk to 37 percent, while that of the higher efficiency equipment had expanded to 35 percent. New air conditioners with efficiencies below 6.4, which in 1976 had accounted for 20 percent of the industry's total shipments, had declined to 5 percent by 1981.[7]

Employment and hours

Employment in the air conditioning, refrigeration, and warm-air heating equipment industry numbered 129,000 persons in mid-1984. It rose 32 percent between 1967 and 1982, or at an average annual rate of 2.2 percent. (Employee hours rose at about the same rate.) Employment reached a peak of 130,000 persons in 1979, and subsequently retreated. This decline was attributable to a 21-percent contraction in production worker jobs between 1979 and 1982, as compared with a 9-percent loss in nonproduction worker jobs. (Employment levels have improved, but have evidently remained below the 1979 high.)

Over the longer term, trends in employee hours displayed patterns of acceleration and retardation similar to those noted for production and output trends. Employee hours in the industry rose during the first 6 years of the review period at an average annual rate much greater than for all manufacturing. Subsequently the rate plummeted:

	Industry	*All manufacturing*
1967–82	2.1	0.0
1967–73	6.8	0.2
1973–82	0.1	0.0

Production workers accounted for 70 percent of total employment, which was the same proportion in both 1967 and 1982—nonproduction workers made up the balance. The number of women workers more than doubled over the period, raising their proportion of total employment from 14 percent to 21 percent. Underlying this increase may have been a shift in the skill composition of the industry's workers to more assembly-type jobs. The rise in the industry's average hourly earnings also slowed relative to the manufacturing average. In 1967, the former was 104 percent of the latter, compared with 96 percent in 1981.

Overtime ran somewhat below the manufacturing average during the review period, suggesting that firms in the industry were inclined to hire new production workers, rather than assign overtime when the workload exceeded certain limits.[8] Turnover rates nonetheless lagged; over the 1967–81 span, they averaged 89 percent of the manufacturing average for accessions, and 91 percent of that for separations. Thus, it appears that employment stability was somewhat greater in the industry than in manufacturing generally.

The skill composition of the industry's work force differs from that for manufacturing as a whole. (The air conditioning, refrigeration, and warm-air heating equipment industry represents 68 percent of the employment of the industry group to which it belongs, and to which the data cited here pertain.)[9] In 1980, craftworkers accounted for 17 percent of total industry employment, compared with 19 percent for all manufacturing. Operatives, however, accounted for a significantly larger proportion—48 percent, compared with 43 percent. The larger component of operatives stemmed from the proportionately greater number of assembly workers in the industry (23 percent) than in all manufacturing (8 percent). The proportion of metalworking operatives in the industry (16 percent) was more than twice as high as for manufacturing generally. By contrast, the occupational distribution of white-collar workers was similar to that for manufacturing. Professional and technical workers made up 8 percent of the industry's workforce (9 percent for manufacturing); clerical workers, 12 percent (11 percent); and managers and administrators, 5 percent (6 percent).

Investment in plant and equipment

Like manufacturing establishments generally, the air conditioning, refrigeration, and warm-air heating equipment industry installed new production equipment at a fairly high rate over the 1967–81 period. (Also like other manufacturing establishments, the industry spent a declining proportion of its total fixed investment outlays on new plant.) However, unlike other manufacturing establishments, firms in the industry spent at a much higher rate during the earlier than the latter part of the review period.[10] For all manufacturing, the reverse held true:

	Industry		*All Manufacturing*	
	Total fixed investment	*Equipment*	*Total fixed investment*	*Equipment*
	(Average annual rates, in percent)			
1967–81	2.2	5.4	3.4	6.2
1967–73	7.4	13.3	−1.3	1.0
1973–81	2.6	4.0	4.2	7.5

The industry's high rate of capital spending in the early part of the period resulted from pressures on capacity, related to high output growth rates. With the abatement of output growth after 1973, fixed investment slowed. The proportion of total fixed investment spent on equipment is as follows:

	Industry	*Manufacturing*
1967–73	69	73
1973–81	87	90

The comparatively high proportion of expenditures for equipment is reflected in the data on the modernization of the industry's metalworking machinery, as reported by the *American Machinist*.[11] (See the section on technological change.) The rates shown, however, obscure large year-to-year fluctuations in the industry's capital spending. This instability was far more marked for the industry than for manufacturing generally. For example, in 1975, the industry's plant and equipment expenditures plummeted 41 percent (in constant dollars), and in 1977, they soared 56 percent. Manufacturing recorded a 9-percent drop, and a 21-percent rise for the same 2 years.

Fixed assets per employee in the industry were 79 percent of the manufacturing average in 1980, compared with 76 percent during 1972 and 1974–76. The rise in the ratio partially reflected the cumulative effects of earlier equipment installations and new plant construction on the value of the industry's fixed assets.

More efficient technology

Air conditioning and refrigeration equipment essentially consists of a compressor driven by an electric motor, and two coils—the condenser, in which the refrigerant is compressed to a liquid, and the evaporator, in which the refrigerant expands into the gaseous state, enabling it to absorb heat from the space being cooled. The heat is transferred from the environment with the aid of fins, mounted upon the evaporator coil. Warm-air furnaces built by the industry are mostly gas-fueled forced-air devices. They include a combustion chamber and a motor-driven blower. The sheet metal housing that shields the equipment is manufactured by the industry, but controls and motors normally are not.

Advances in the manufacture of air conditioners, refrigeration equipment, and warm-air furnaces have been linked chiefly to technological progress in metalworking machinery, welding, methods of storage and transfer of parts, and assembly. They are also related to improvements in product design.

The production of air conditioners, refrigeration equipment, and warm-air furnaces basically involves the cutting and forming of metal, as well as welding, brazing, and soldering of components. Efforts to improve efficiency usually focus upon these operations, and on plant layout. Auxiliary operations, such as materials handling, painting, testing, and packaging have received increased attention in recent years.

The most recent *American Machinist* inventory of metalworking equipment indicates that, in 1983, 30 percent of all metalcutting and metalforming machine tools used in the industry were at most 10 years old. In 1968, the proportion was the same for metalcutting tools, but only 25 percent for metalforming tools. The industry has steadily improved its metalworking equipment, by and large maintaining the same proportion of newer equipment during 1973–83 as during 1958–68. The higher end of the age distribution, however, shows an increase in the proportion of older metalworking equipment in the industry. The share of metalcutting machine tools 20 years and older rose from 25 percent in 1968 to 32 percent in 1983, and the share of metalforming tools, from 25 percent to 37 percent. However, the relative increase in older machine tools cannot be readily interpreted as a loss in efficiency, inasmuch as the *American Machinist* inventory does not take into account the retrofitting of older machines with up-to-date components and control devices.[12]

The efficiency of the industry's metalworking equipment has been significantly enhanced by an 11-fold rise in the number of numerically controlled (NC) machine tools. In 1983, NC machine tools accounted for 13 percent and 17 percent of metalcutting and metalforming tools 9 years old or less. In 1968, when NC machine tools were not yet widely diffused, the proportions were less than 1 percent. The percentage increase in the number of NC tools understates the increase in the output capabilities which the installation of such tools spells. According to the *American Machinist*, the number of machine tools in all metalworking industries declined from 16 per 1,000 population in 1968 to fewer than 10 in 1983. "This represents in part the greater productivity of machine tools, in part the simplification of design of many products, so that less machining is required."[13] This statement also applies to the industry reviewed here: the number of machine tools in the industry's shops dropped by one-third between 1968 and 1983, while output (over the 1968–81 period) more than doubled. Thus, the output capability of metalworking equipment in the industry rose nearly threefold over the study period, with that rise likely to be largely attributable to NC-equipped machine tools.[14]

Examples of how improved metalworking technology has helped to raise output per hour may be drawn from the sheet metal operations in the industry's larger shops, and from the fabrication of some of the major components of its products. In punching sheet metal, templates were conventionally affixed to the press so as to obtain required shapes. Templates have been increasingly replaced, however, by taped instructions fed to the press, which greatly speeds output and ensures greater precision of the finished shape. Setup time of the press has been reduced to as little as one-twentieth of the conventional operation. In a related operation, the press, after the sheet metal blank has been placed automatically, is programmed to select 1 of up to 30 built-in punching tools from its turret, and to activate the tool selected.[15] Bending of metal parts has likewise been increasingly automated, the bending apparatus being preset to several sequential settings (so as to graduate the bending process.) Setup time here has declined to an estimated 10 percent of what it had been prior to automation. Despite their being automated, these metalworking processes continue to require close monitoring by trained operators. The operator may monitor two or more machines at the same time, or may be engaged in such auxiliary tasks as placing and removing work pieces.[16]

Some of the more advanced shops in the industry feature such machine tools as high-capacity drills, which may drill all the holes in an air conditioning compressor vessel in one or two operations. (The holes are for accomodating bolts.) Older drilling machines, still widely in use, have much lower capacity and speed. Automatic tool wear adjustment is normally also a feature of NC machine tools, but at times this feature is not desired or used. Replacement of a tool bit is then left to the discretion of the operator assigned to monitor the entire machining process. In small-lot production, loading and unloading the work piece may be done manually. [17]

Improved productivity in the fabrication of air conditioning equipment components during the review period is exemplified by the coil manufacturing process. The coil (made of copper or aluminum) is the heart of the heat exchanger. The refrigerant is pumped through it (by the compressor) to absorb heat from the surrounding space. The coil originates as tubing on a large roll. In the more advance shops, the rolled tubing is automatically straightened, cut to length as specified in, and controlled by, a taped program, and automatically bent to the shape of a U (or hairpin). This operation has come to be performed by one person, where 10 years or so ago, four persons were required to shear the tube manually and insert it into a bending device.

The U-shaped coil is inserted into a nest of aluminum fins. The fins aid in absorbing heat from the refrigerant. The fabrication of fins is usually highly mechanized, precut aluminum blanks being punched to form them, and to accomodate the coils. Numerically controlled punch presses featuring up to 27 spindles are used in the larger shops. However, the number of blanks that may be punched at a time is limited because punching tends to break rather than cut the metal, and breaking forms rims that cannot be tolerated. Where fins are produced in quantity, punch presses may not be numerically controlled, because longer setup times are usually justified by the longer runs.

Loading and unloading of the punch presses has usually been mechanized in the larger plants, so that the fins emerge stacked as nests. The coils are then inserted manually. Manual insertion is still preferred because it prevents "binding." The operator can readily control the pressure he exerts in inserting the individual coils, which is not (as yet) the case for mechanical insertion where undue pressure may damage ("bind") the coil. The coils are then brazed together or soldered to form a continous loop. Brazing or soldering is still performed by means of hand-operated devices to ensure leakproof joints and the continuity of the loop, so as not to "blind-alley" them).[18]

The fabrication of reciprocating compressors provides other examples of the reduction in unit labor requirements which the industry seeks. Compressors, driven by electric motors (manufactured outside the industry), function to increase the density of the refrigerant to the liquid state. Basically, the reciprocating compressor consists of a piston sitting on a rod connected to the motor; and a cyclinder, against the head of which the piston moves, compressing the refrigerant. Where compressor components are produced in quantity, multistation machinery arranged in circular (or "dial") form has come to be used. Yet, loading and unloading of the workpiece, and transferring it between groups of dial machinery, is still widely done manually. Some establishments began to install automatic transfer lines toward the end of the review period, affording automatic positioning of the workpiece, as well as automation of most other metalworking operations (such as milling, drilling, reaming, and so forth). Transfer lines require usually one-half or less of the labor per unit of the more conventional equipment; so-called "uptime," that is the time during which the machinery is fully operational, is estimated to be 20 percent higher.[19] However, for the installation of such machinery to be economical, volume of compressors with 4½ to 6 tons of ice equivalent must run well in excess of 250,000 units annually, and of compressors with 2 to 4½ tons of ice equivalent must exceed 500,000 annually.[20]

Changes in product design have, in some instances been combined with technological advances. Thus, a cylindrically shaped air conditioning machine has been developed that permits several hundred feet of continual coil (or tubing) to be wrapped around a mandrel in one mechanical process. This increases the heat transfer area, hence the efficiency of the machine. It also minimizes the jointing of coil ends (as described earlier), and thus, the leakage of refrigerant. Fins consist of many hundreds of tiny aluminum pieces glued to the tubing's surface. Unit labor requirements in mounting such tubing are estimated at 20 to 30 percent of those for the manual insertion of U-shaped coils into nests of fins and the fabrication of such fins.[21]

Product design and technological advance have also been combined in the case of a thermostatic valve body for automotive air conditioning. After the valve body was redesigned, it could be fabricated by means of a 43-spindle metalworking machine which combines automatic indexing, milling, drilling, counterboring, tapping, and other operations. Material costs were reduced, assembly facilitated, and quality improved. The machine replaced as many as 11 standard machines run by 30 workers.[22]

A fundamental design change in air conditioning equipment and warm-air furnaces during the review period made them more energy-efficient (see the section on output). The relevant design changes usually involved finer tolerances, hence greater precision machining, especially of compressor components. Precision machining in turn has been facilitated by—and has spurred the adoption of—NC metalworking machinery. Functional testing, furthermore, has been upgraded by such electronic devices as automatic calibration stations, which can be programmed for many settings at a time, and which require little attendance.[23] Assembly appears also to have been improved by the better "fit-up" of the more precisely machined components.

Industry structure

Industry concentration increased over the period reviewed; in 1977, the 8 largest companies accounted for 51 percent of the industry's value of shipments, compared with an estimated 45 percent in 1967.[24] The 20 largest companies accounted for 67 percent of the value of shipments in 1977, as against 62 percent in 1967. Moreover, the concentration ratio for 1967 was higher than for 1963. These increases suggest underlying growth over time in economies of scale, a factor that usually engenders productivity improvement.

Employment, too, was concentrated in the larger establishments. In 1977, 50 percent of the industry's employees worked in 31 (or 4 percent) of the 860 establishments classified in the industry. At the lower end of the employment size stratification, just over 10 percent of all employees in the industry worked in 75 percent of all establishments. It is noteworthy that the size distribution of capital expenditures closely followed the size distribution of employment—such that, for example, nearly one-half of all such expenditures were made by only 4 percent of all establishments in the industry (that is, those with 1,000 or more employees.) In line with the increase in concentration ratios, the larger establishments raised their share of the industry's total employment over time.

Outlook

Equipment. Continued productivity improvement is indicated for the industry. As the *American Machinist* inventory of metalworking equipment in the industry suggests, diffusion of NC machine tools is far from complete. If past trends in diffusion persist, productivity gains are likely to be generated. Moreover, the larger, more advanced shops plan to install flexible manufacturing (FM) systems, which will make small-lot production of larger air conditioning, refrigeration, and heating equipment more efficient.[25] One establishment, which is installing a FM system to produce reciprocal compressors, expects direct labor requirements to be reduced by more than 80 percent, as compared with conventional production methods. Another establishment, which produces large evaporators in lots of less than 100, also plans to fabricate them by FM methods. Such evaporators require up to 5,000 different metal shapes. In combination with NC machine tools, plant management expects FM to save up to 50 percent in unit labor requirements, cut lead time by nearly one-half, and cope with declining lot size and more exacting tolerances more efficiently. Management also foresees significant savings in materials and inventory costs.[26]

The cutting of steel, a large-scale operation in the bigger shops, should also become progressively more automated. The cutting and punching of steel is often still done by an operator using templates and judging by sight how to minimize waste in laying them out. Templates and operator judgment have begun to be replaced by computer-instructed cutting machines, where the computer calculates the most economical distribution of cuts. The computer memory also records odd pieces of steel that might be used in future work. With template labor and layout estimation by an operator eliminated, five times as much steel may be processed in the same period as previously. Also, material savings of up to 60 percent are expected.[27]

In welding operations, robots are increasingly being used, but for complex surfaces, skilled welders who may be subject to certification are still necessary. The use of a certified welder is frequently required by a code authority, such as the American Society of Mechanical Engineers, or by a customer, such as the U.S. Navy. Plant managers generally expect more versatile robots, which sense the complexities of the surfaces to be joined, to become available. But the laborsaving potential of such robots hinges upon the extent to which code requirements are modified.[28]

The efficiency of auxiliary operations in the industry is also likely to improve. Thus, while many plants feature partially automated storage of parts and components, work stations are still usually supplied by means of manually operated carts or small trucks. (Heavier and bulkier parts may be moved by overhead crane, activated by radio control.) Some plants in the industry which produce in quantity expect to install fully automated storage and delivery systems that convey parts to work stations upon command. Management in one such plant expects labor savings of 50 to 75 percent, compared with the partially automated system, as well as the near elimination of damage from multiple handling.[29]

Employment. The occupational compositon of the industry's employment is not expected to change very much during the 1980's, except for growth in the proportions of engineers, engineering and science technicians, and computer specialists. Employment in these occupational categories has been projected by the Bureau of Labor Statistics to rise 27 percent between 1980 and 1990, compared with a 15-percent increase for employment in the industry as a whole.[30] The proportion of craftworkers and operatives has been projected to remain unchanged.

The projections signify increased reliance upon engineers and technicians in designing and monitoring more efficient production processes. The projections do not, however, indicate an accelerating trend toward either "deskilling" craftworkers or displacing operatives. In 1990, craftworkers will constitute an estimated 16 percent of total industry employment, and operatives, 48 percent—the same as in 1980. The proportion of professional, technical, and related workers in the industry is estimated to rise from 8 percent to just under 9 percent. □

———*FOOTNOTES*———

[1] The industry for which labor productivity is discussed here has been designated as number 3585 in the *Standard Industrial Classification Manual (1972)*, published by the Office of Management and Budget, and titled "Air Conditioning and Warm Air Heating Equipment and Commercial and Industrial Refrigeration Equipment." The industry includes establishments primarily manufacturing such equipment, as well as soda fountains, humidifiers, and dehumidifiers.

Average annual rates discussed in the text are based on the linear least squares of the logarithms of the index numbers. The measures of productivity and related variables will be extended annually, and will appear in the annual BLS Bulletin, *Productivity Measures for Selected Industries.*

[2] Establishments which primarily manufacture household refrigerators and freezers are classified as industry 3632 in the *Standard Industrial Classification Manual.*

[3] Based on input-output calculations for 1972.

[4] *Statistical Abstract of the United States, 1982–83* (Bureau of the Census, 1982), p. 752.

[5] Barbara Bingham, "Labor and material requirements for shopping center and retail store construction," *Monthly Labor Review*, forthcoming.

[6] *Residential Alterations and Repairs, Construction Reports, Annual 1981* (U.S. Department of Commerce, 1981).

[7] *Comparative Study of Energy Efficiency Ratios*, (Arlington, Va., Air-conditioning and Refrigeration Institute, April 1983). See also *Statistical Panorama*, published each April by *The Air Conditioning, Heating, and Refrigeration News*.

[8] Overtime in SIC 3585 (manufacturing = 100):

1967	91	1975	65
1968	75	1976	97
1969	94	1977	91
1970	87	1978	100
1971	79	1979	82
1972	97	1980	79
1973	84	1981	79
1974	73		

[9] Figures cited in this section are based on data developed by the Bureau of Labor Statistics.

[10] The census data for plant and equipment were converted to a constant-dollar basis from the current-dollar figures by applying the implicit price deflator for structures and producers' durable equipment, as published in *The Economic Report of the President* (U.S. Government Printing Office, February 1983), p. 166.

[11] "The 13th *American Machinist* Inventory of Metalworking Equipment 1983," *American Machinist*, November 1983, pp. 113 ff.; and unpublished inventory data, by courtesy of *American Machinist*.

[12] *Ibid.* The decision to classify a metalworking machine in a lower age group when retrofitting it with new components is left to the firm that completes the inventory forms. These decisions tend to be conservative.

[13] *Ibid.*, p. 123.

[14] Horst Brand and Clyde Huffstutler, "Productivity in the pump and compressor industry," *Monthly Labor Review*, December 1982, pp. 38–45. It should be noted that the productive capability of machine tools in the industry, as in industries in general, has been increased also by the large proportion of metalworking equipment in the lower group that is not numerically controlled. For example, three-quarters of all establishments in the industry surveyed by *American Machinist* reported drilling machines that were not numerically controlled (compared with 7 percent with NC drilling machines). One-quarter of all drilling machines that were not numerically controlled were less than 9 years old, and about two-thirds were under 20 years old.

[15] Industry information. See also *American Machinist*, December 1981, p. 57, describing a computer-NC notching press, and noting reductions in labor requirements.

[16] Industry sources.

[17] Industry sources.

[18] Industry sources.

[19] Industry sources.

[20] Industry sources.

[21] Industry sources.

[22] See *American Machinist*, Mar. 15, 1975, pp. 65–67.

[23] *Ibid.*, and industry information.

[24] While the data for 1967 include only air conditioning and refrigeration equipment manufacturers, the rise in the concentration ratio in 1972 is unlikely to have stemmed merely from the inclusion that year of warm-air furnace manufacturing establishments.

[25] Industry information.

[26] Industry source. Flexible manufacturing systems depend on automatically adjustable metalworking equipment, often linked with robots or other automatic transfer devices. See *American Machinist*, December 1981, pp. 55–56.

[27] Industry source.

[28] "Major technology changes in fabricated structural metal," *The Impact of Technology on Labor in Five Industries*, BLS Bulletin 2137 (Bureau of Labor Statistics, December 1982), pp. 37–39. See also *American Machinist*, January 1980, p. 63, and June 1980, p. 69.

[29] Industry source.

[30] "The "low" trend version of three alternative projections by BLS is used here. See Valerie A. Personick, "The job outlook through 1995: industry output and employment projections," *Monthly Labor Review*, November 1983, pp. 24–35.

APPENDIX: Measurement techniques and limitations

Indexes of output per employee hour measure changes in the relation between the output of an industry and employee hours expended on that output. An index of output per employee hour is derived by dividing an index of output by an index of industry employee hours.

The preferred output index for manufacturing industries would be obtained from data on quantities of the various goods produced by the industry, each weighted (multiplied) by the employee hours required to produce one unit of each good in some specified base period. Thus, those goods which require more labor time to produce are given more importance in the index.

In the absence of physical quantity data, the output index for the industry which manufactures air conditioning, refrigeration, and warm-air heating equipment was constructed using a deflated value technique. The value of shipments of the various product classes was adjusted for price changes by appropriate Producer Price Indexes to derive real output measures. These, in turn, were combined with employee hour weights to derive the overall output measure. These procedures result in a final output index that is conceptually closer to the preferred output measure.

Employment and employee hour indexes were derived from data from the Bureau of Labor Statistics. Employees and employee hours are considered homogeneous and additive, and thus do not reflect changes in the qualitative aspects of labor, such as skill and experience.

The indexes of output per employee hour relate total output to one input—labor time. The indexes do not measure the specific contribution of labor, capital, or any other single factor. Rather, they reflect the joint effects of such factors as changes in technology, capital investment, capacity utilization, plant design and layout, skill and effort of the work force, managerial ability, and labor-management relations.