Multifactor productivity: refrigeration and heating equipment industry

Multifactor productivity gains averaged 1.5 percent per year over the 1967–94 period; to comply with Federal legislation, the industry shifted from chlorofluorocarbons, an important input in the production process, to environmentally safer substitutes

Paul V. Kern
and
Patricia S. Wilder

Multifactor productivity in the refrigeration and heating equipment industry increased at an average annual rate of 1.5 percent over the 1967–94 period.[1] This industry's output includes air conditioners, refrigeration equipment and systems, electric heat pumps, furnaces, refrigerated display cases, soda fountains, beer dispensers, and snowmaking machinery. Multifactor productivity is a measure used to analyze the overall economic efficiency of an industry. It relates the growth of the industry's output to the growth rate of the combined inputs of labor, capital, and intermediate purchases.

An important input for the refrigeration and heating equipment industry had been chlorofluorocarbons (CFC's), a chemical compound used since the 1930s. By Federal enactment, however, CFC's were phased out because they were linked to depletion of the ozone layer in the atmosphere.[2] As a result, the industry has had to allocate a substantial amount of resources to the transition away from CFC's.

This article examines detailed productivity, output, and input data in the manufacture of refrigeration and heating equipment to provide measures of multifactor productivity growth over a 27-year period. Special emphasis is placed on the "productivity falloff" that began in 1973. The article also includes descriptions of recent production technology, new designs and methods of manufacturing, and market influences that could influence industry output and input.

Productivity

Since 1984, the Bureau of Labor Statistics has published an index of output per employee hour, or labor productivity, for the refrigeration and heating equipment industry. (See appendix for a description of the methodology and data for the industry, designated as SIC 3585.) Labor productivity relates output to the input of labor, while multifactor productivity relates output to the combined inputs of labor, capital, and intermediate purchases (materials, purchased energy, and purchased services). Labor productivity does not measure the exact contribution of labor, but reflects many influences that affect the use of labor, such as changing technology; economies of scale; substitution of inputs of capital and intermediate purchases for labor; managerial skills; and the level of experience and education of the work force. While the multifactor productivity measure reflects many of these influences, it does not reflect changes in capital relative to labor and in intermediate purchases relative to labor.

Labor productivity in the industry increased at an average annual rate of 1.7 percent over the entire period studied (table 1), while in total manufacturing the rate was 2.7 percent (measured from 1967 to 1993). Over the same period, multifactor productivity rose 1.5 percent per year in the in-

Paul V. Kern and Patricia S. Wilder are economists in the Office of Productivity and Technology, Bureau of Labor Statistics.

dustry, while in the total manufacturing sector of the economy, it advanced 1.1 percent per year (also from 1967 to 1993).[3] The 1.5-percent rate of growth in multifactor productivity resulted from a 3.6-percent average annual increase in output and a 2.1-percent average annual gain in combined inputs (table 2). Analyzing the 1967–94 period in more detail, we find that labor productivity rose rapidly, at 5.2 percent per year, while multifactor productivity increased 3.6 percent per year during 1967–73 (table 3).

The refrigeration and heating equipment industry did not escape the productivity falloff that affected most manufacturing industries between 1973 and 1979. Both labor productivity and multifactor productivity growth rates fell sharply from the 1967–73 period to the 1973–79 period (chart 1). Labor productivity dropped 0.3 percent per year for the latter period, down from a 5.2-percent per year increase for the 1967–73 period. Multifactor productivity growth fell from an annual rate of increase of 3.6 percent to a 1.9-percent rate for the same periods—a slowdown considerably smaller than the 5.5-percentage-point falloff that occurred in labor productivity. For the 1979–94 period, labor productivity growth recovered from the 0.3-percent-per-year decrease during 1973–79 to post a 1.1-percent average annual *increase*. Multifactor productivity growth was subdued, rising just 0.6 percent each year after 1979.

The influence of capital on output per employee hour, referred to as the "capital effect," is measured as the change in the capital–labor ratio multiplied by the share of capital costs in total costs of output. Analogous to the capital effect is the "intermediate purchases effect" which is derived by multiplying change in the intermediate purchases–labor ratio by the share of intermediate purchases in the total cost of output. Labor productivity growth equals the sum of these two effects plus multifactor productivity growth. For the entire 1967–94 period, the capital effect was 0.0 percent per year, while the intermediate purchases effect averaged 0.1 percent annually. Although the capital effect and the intermediate purchases effect were negligible for the entire period studied, they did vary in the subperiods. During 1967–73, the capital effect contributed 0.2 percentage point to the growth rate of labor productivity and the intermediate purchases effect contributed 1.3 percentage points. For the period 1973–79, the capital effect equaled –0.1 percent on average, while the intermediate purchases effect declined 3.3 percentage points, to –2.0 percent per year. During the 1979–94 period, the capital effect decreased slightly to a –0.1-percent average annual rate, while the intermediate purchases effect increased, to 0.6 percent per year.

Technology change

Production techniques and, hence, rates of productivity, in this industry have been affected by new technology from a product's start to finish. With the introduction of new methods, the industry strives to reduce wasted materials, decrease rejected finished parts and products, and diminish labor requirements. Computer-aided design (or CAD) assists an engineer in designing a new product by taking over repetitive tasks, warning of inconsistencies in measurement, and increasing the designer's usable memory many times over by storing almost unlimited data. Computer-aided manufacture (or CAM) guarantees that an engineer's specifications are carried out to degrees of accuracy that were impossible before the advent of microprocessor-controlled production equipment.

Table 1. Multifactor and related productivity measures in the refrigeration and heating equipment industry (SIC 3585), average annual rates of change, 1967–94

[Percent]

Period	Multifactor productivity	Output per hour	Output per unit of capital	Output per unit of intermediate purchases
1967–94	1.5	1.7	1.4	1.4
1967–73	3.6	5.2	3.3	3.0
1973–79	1.9	–.3	–.3	3.5
1979–94	.6	1.1	1.3	.0

Table 2. Output and inputs for the refrigeration and heating equipment industry(SIC 3585), average annual rates of change, 1967–94

[Percent]

Period	Output	Combined inputs	Hours	Capital	Intermediate purchases
1967–94	3.6	2.1	1.9	2.2	2.2
1967–73	13.5	9.6	7.9	9.8	10.2
1973–79	–.1	–2.0	.1	.1	–3.5
1979–94	1.4	.9	.4	.1	1.4

Table 3. Output per hour, multifactor productivity, and related measures (SIC 3585), average annual rates of change, 1967–94

[Percent]

Measure	1967–94	1967–73	1973–79	1979–94
Output per hour[1]	1.7	5.2	–0.3	1.1
Equals Multifactor productivity	1.5	3.6	1.9	.6
Plus Capital effect[2]	.0	.2	–.1	–.1
Plus Intermediate purchases effect[3]	.1	1.3	–2.0	.6

[1] Each measure presented in this table is computed independently. Therefore, multifactor productivity, the capital effect, and the intermediate purchases effect might 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 capital costs 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 intermediate purchases costs in the total cost of output.

Engineering firms developing new heating and cooling products have embraced CAD technology. These systems allow a shop to get more work, of a more complex nature, from fewer engineers. The systems can even be programmed by senior engineers to coach the less experienced, to ensure that all work meets design, cost, and producibility standards set by the firm.[4] Designing any new product or component usually involves several stages, at which modifications are tested within the CAD environment. This is the point at which a CAD system saves significant labor hours and material. The "brain" of these systems can modify drawings and actually test the modifications in minutes, making it unnecessary to completely redraw the component, or to manufacture one version to test a change (an expensive and time-consuming process).[5] Most CAD systems can scrutinize a component for noise, vibration, stress, buckling, and fatigue.[6]

Computer-aided manufacturing (or CAM) has allowed a plant in Indiana to make finished motor vehicle air conditioners from raw castings, with almost *no* manual handling. The plant, which makes compressors for cars and light trucks, has 5 miles of conveyors—all monitored and controlled by six microprocessors. Together, the conveyors take up almost 200,000 square feet of plant space. Production processes that once were performed as separate operations, and often manually, are now integrated into a "system approach." [7]

Many of the new technologies introduced into this industry are aimed at improving control of processes such as metal cutting and bending. Precise cutting of metal not only reduces waste, but also is essential "down the line," where automated equipment requires very close tolerances. A Minnesota plant uses machine vision modules to detect any flaws on metal to be used to make freezer coils. The vision modules detect irregularities and direct controllers to reverse the flow of the material and cut off the flawed portion. This reduces labor and material requirements while producing fewer defective products. The plant also has been able to switch to a lighter gauge steel. This is because the new drives (which move and shape the steel) improve handling to such an extent that the material is less likely to be damaged.[8]

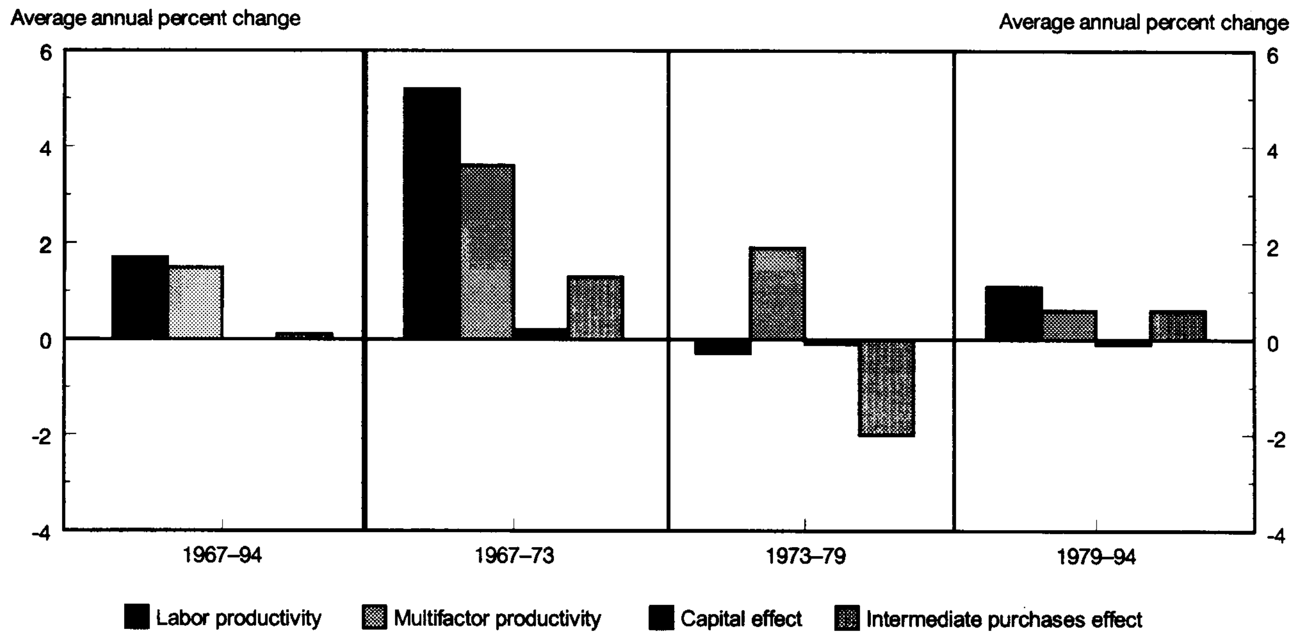
Environmental concerns will continue to alter the designs and methods of manufacturing in the refrigeration and heating equipment industry for some time. Meanwhile, engineers and designers have begun discussing and practicing the "design for disassembly" concept in this, and other industries as well. The goal of this concept is to construct a product so that it can be easily disassembled into its component parts for simplified recycling. At present, the recycling of refrigeration and heating equipment is limited because of the large quantities of labor needed to take the equipment apart. This new theory of design will require yet newer technologies of the industry and of its suppliers of intermediate inputs.[9]

Output

Changes in output in the refrigeration and heating equipment industry respond to many variables, including new residential and nonresidential construction, renovation of existing structures, automobile sales, Federal legislation regarding the environment, and the general health of the economy. For the entire 1967–94 period, output in the industry increased 3.6 percent each year on average, compared with a 2.5-percent average annual increase for all manufacturing (measured from 1967 to 1993). This industry is highly cyclical, with sharp swings in output: the sharpest increase occurred during 1972, when it posted a 32.5-percent jump in output; the deepest drop took place in 1975, bringing output down 35.5 percent from the previous year. Two industries, motor vehicles and equipment and building construction, dominate the demand for refrigeration and heating equipment. For 23 of the 27 years between 1967 and 1994, changes in output in the industry move in the same direction as changes in output of the motor vehicles and equipment industry. The relationship between new construction and the demand for new refrigeration and heating equipment also is strong.

A significant market for the industry's output is retrofit and reconstruction. This involves work on commercial buildings intended to upgrade cooling and heating equipment to meet new standards, increase the appeal of unleased space, and reduce indoor environmental problems. The trend for the retrofit and reconstruction market appears to be upward. Specifically, legislation at the Federal level, which began the CFC phaseout schedule, will spur the demand for retrofit and replacement.[10] In the United States, there are more than 130 million motor vehicle air conditioners, 5 million commercial refrigeration

Chart 1. **Multifactor productivity and its relationship to labor productivity in the refrigeration and heating equipment industry (SIC 3585), 1967–94**



systems, and 80 thousand air-conditioning units for commercial and institutional buildings running on CFC's. Many of these components will have to be replaced or retrofitted.[11]

For many of the establishments in this industry, international sales represent as much as 35 percent of total revenues. In 1993, the value of U.S. imports of refrigeration and heating equipment increased almost 8 percent, while the value of the exports of this industry increased 12 percent. Exports will continue to increase due to the economic and social changes taking place in Eastern Europe and the former Soviet Union. More significant is the liberalization of trade made possible by the North American Free Trade Agreement of 1994. This should create excellent opportunities for the industry to expand its exports to Canada and Mexico (its leading foreign customers).[12]

The refrigeration and heating equipment industry is currently experiencing a boom in the production of one of its products. Shipments of air conditioning systems for institutional and commercial buildings (such as skyscrapers, schools, and hospitals) have grown dramatically. These units, called chillers, are needed to replace older, less efficient systems that rely on CFC's. According to a survey by the Air Conditioning and Refrigeration Institute, "U.S. shipments of chillers to building owners around the world jumped 32 percent in 1995 to a record 9,444 units, of which about 40 percent were used in America to replace CFC chillers, ..." Moreover, this surge will continue for several more years because the institute's survey also showed that, "...65,375 or 82 percent of...chillers in the U.S. were still using CFCs on January 1, [1996] when a ban on CFC production went into effect."[13]

Only a few years ago, the outlook for this industry was not encouraging. At the time, producers complained of the potential for equipment shutdowns, the need for employee layoffs, and low inventories. This was primarily due to legislation requiring stringent cutbacks of CFC compounds before the replacements had been invented. Research and development, however, have led to the design of efficient CFC-free refrigeration and air conditioning products, which has helped increase the demand for the industry's output.

Inputs

Labor. Over the entire 1967–94 period, labor input (measured by employee hours) increased 1.9 percent per year, on average. Again, this hides the divergence between pre- and post-1973 trends for the industry. From 1967 to 1973, labor input in SIC 3585 grew at an average annual rate of 7.9 percent, but from 1973 to 1979, it increased just 0.1 percent per year. In the final period, 1979–94, employee hours edged up 0.4 percent each year, on average.

In 1967, there were 81,500 people employed by the refrigeration and heating equipment industry. The average hourly earnings for production workers in the industry at that time were $2.93 (in current dollars), compared with $2.82 for all manufacturing. In that same year, 70 percent of all industry employees were production workers, compared with 74 percent in all manufacturing. In 1994, the level of employment reached more than 130,000—an impressive recovery from the 1991 level of 115,000 employees. By 1994, average hourly earnings of production workers were $11.80 in the industry, compared with $11.62 in all manufacturing.[14]

In 1995, employment in the industry had swelled to a new peak of 139,000. This is in stark contrast to employment in the total manufacturing sector, which last peaked in 1979.[15] Employment levels in the next few years could surpass the 1995 peak for the reasons discussed earlier.

Capital. As measured in BLS multifactor productivity studies, capital is the flow of services derived from the equipment, structures (primarily buildings that house the production process), finished goods, work-in-process, and materials and supplies inventories that are kept on hand in the firm, as well as the land on which plants are located. Financial assets are not included in the measure.

Capital services in the refrigeration and heating equipment industry grew at an average annual rate of 2.2 percent between 1967 and 1994. Reflecting the industry's tremendous growth through the early 1970s, capital services averaged a 9.8-percent annual increase during the 1967–73 period. However, gains slowed sharply after 1973, to just 0.1 percent per year during 1973–79. This slowdown continued for the 1979–94 period with capital services increasing at the same rate of 0.1 percent.

From 1967 to 1994, measures of the services of capital structures and land moved similarly to that for total capital, increasing at average annual rates of 2.0 and 2.7 percent, respectively. That for equipment rose even faster, at an average annual rate of 4.9 percent. Inventories were steady at 0.0 percent per year, on average. In the first interval, 1967–73, equipment services rose almost 13 percent each year, then fell off to a gain of 4.4 percent annually during 1973–79. Between 1979 and 1994, these services grew even more slowly, at an annual rate of 2.1 percent.

While inventories as a whole were cyclical for this industry, when viewed in more detail, a different picture emerges. For unitary (noncomponent) products, particularly window air conditioning units, inventories change with the seasons and the severity of seasons. A summer that is cooler than average would leave inventories higher than average for the year. Also, the suppliers of materials to the industry sometimes offer incentives, such as attractive financing, that will induce manufacturers to stock up on inventory. For the component products, such as industrial and commercial heating/cooling units for whole buildings, there generally is no inventory. The product itself is so specialized that the materials are not ordered until the buyer has committed to the purchase.[16]

In 13 years, the services of structures declined; these annual reductions never exceeded 2 percent. For the entire period, 1967–94, the measure for structures increased 2.0 percent each year, on average. However, the overall increase masks the high pre-1973 gain of 8.8 percent each year and the drop-off to just a 0.2-percent gain each year after 1973.

Intermediate purchases. Intermediate purchases consist of the raw materials, energy (in the form of fuels and electricity), and purchased services used in the production of the industry's output. Materials make up more than 90 percent of the value of intermediate purchases for the refrigeration and heating equipment industry, with services ranging from 6 percent to 9 percent of that value, and fuels and electricity, the remainder.

The input of intermediate purchases increased 2.2 percent each year, on average, between 1967 and 1994, but this overall rate hides the large difference between the pre-1973 and the post-1973 periods. During 1967–73, input of intermediate purchases increased by more than 10 percent each year, on average, but in 1973–79, this component *decreased* 3.5 percent per year. The 1979–94 interval showed a cessation of the downward trend of the use of intermediate inputs, with an average annual increase of 1.4 percent each year. The use of intermediate purchases generally follows that of output. However, when output is increasing faster than the use of intermediate purchases, the result is a gain in intermediate purchases productivity (the ratio of output to intermediate purchases). From 1967 to 1994, intermediate purchases productivity gained 1.4 percent each year, on average. The rates of change in intermediate purchases productivity were 3.0 percent for the 1967–73 period, and 3.5 percent for the 1973–79 period. The last period, 1979–94, shows a complete slowdown in the growth of this measure, to an average 0.0 percent per year.

The price of intermediate purchases for the refrigeration and heating equipment industry increased 5.1 percent, on average, between 1967 and 1994. Producers are continually trying to discover ways of substituting one group of inputs for another, to reduce the cost of a given level of output. A rise in price encourages substitution away from the relatively costly input for a cheaper alternative. In this industry, from 1967–73, the price of materials was increasing only 4.4 percent each year, on average, while the cost of labor was increasing 7.8 percent per year. The intermediate purchases effect was an average 1.3 percent annually between 1967 and 1973. In the second period, 1973–79, this trend was reversed as labor became relatively inexpensive (with the cost increasing 6.5 percent annually, on average) while materials became more costly (with the price rising 10.5 percent each year, on average). The intermediate purchases effect declined to an average –2.0 percent per year in this interval. The last period shows the prices of materials (3.2 percent) and labor (3.9 percent) increasing at more equal annual average rates. The intermediate purchases effect was closer to zero, at an average annual rate of 0.6 percent each year, because less incentive for substitution existed in this period.

The 1992 Census of Manufactures details almost 40 categories of materials for the heating, air conditioning, and refrigeration equipment industry. Motors and generators made up the largest portion of the total value of these materials at 13 percent. The second and third largest shares were for carbon steel (7 percent) and automatic temperature controls (5 percent). Refrigerant gases accounted for less than 1 percent of the value of materials consumed by this industry in 1992, but this understates their importance to refrigeration and heating equipment manufacturers.[17] CFC's were used as an evaporative agent in many refrigeration and mobile-air conditioning applications. They also were used as a blowing agent to form the insulation that keeps the cold air inside the refrigerated space. CFC's are very good at both of these functions. Being large, stable compounds, they have a very low thermal conductivity figure and are nontoxic, nonflammable, and noncorrosive. As insulation, CFC's were blown into liquid plastic and forced, under pressure, into cavities between the walls of appliances. There, they served as insulators and a stress member of the cabinet itself. Because CFC molecules are large, they do not escape readily through the solidified plastic, as oxygen or carbon dioxide would. The low thermal conductivity of CFC-based insulation allows the compressor to run less often, reducing the energy used by the product. The use of CFC-based insulation increased in the 1970s, so that manufacturers could comply with new regulations regarding the efficiency of their products. The refrigeration and heating equipment industry's inputs and output are regulated, to varying degrees, by the Montreal Protocol (an international treaty regarding ozone depletion); and the U.S. Clean Air Act Amendments, National Appliance Energy Conservation Act, Energy Policy Act, and Toxic Substances Control Act.

As mentioned earlier, the refrigeration and heating equipment industry began using CFC's as inputs in the production process in the 1930s. Decades later, the Montreal Protocol (1987) and Clean Air Act Amendments (1992) mandated that the industry substitute away from these materials to safeguard the atmosphere. Although the costs of developing the substitutes themselves were borne chiefly by the industrial inorganic chemicals industry, the refrigeration and heating equipment industry required new manufacturing techniques, because the ozone-safe coolants are not perfect substitutes for the originals. Production workers had to be trained to use the new materials, which are toxic, corrosive, and combustible—characteristics that CFC's do not share.[18] To handle these substitute coolants, new compressor, seal, and blower technology needed to be devised.

The development and adoption of these technologies used resources that might otherwise have gone toward improving efficiency in the production process. This could help explain the slowdown in multifactor productivity growth in the industry during the post-1979 period. After rising 3.6 percent per year between 1967 and 1973 and 1.9 percent per year between 1973 and 1979, multifactor productivity increased at an average annual rate of just 0.6 percent in the 1979–94 period.

Initially, the industry substituted hydrochlorofluorocarbons (HCFC's) for CFC's in the production process; HCFC's do only 2 percent to 10 percent as much damage to the ozone layer as CFC's.[19] However, *their* use is to become limited by the year 2003.[20] The industry is already replacing these second-generation coolants with the third, hydrofluorocarbons (HFC's). HFC's do *no* damage to the ozone layer *but* they are a greenhouse gas and may become limited-use inputs in the future. The fourth-generation coolant may not be a chemical at all. Thermoacoustic cooling is a recent discovery in which sound and inert gas cool an enclosed space.[21]

The refrigeration and heating equipment industry will continue to face challenges arising from the need for safer coolants in its products; meeting those challenges might restrain productivity growth in the near future.

OUTPUT PER HOUR, or labor productivity, in the refrigeration and heating equipment industry increased at an average annual rate of 1.7 percent between 1967 and 1994. Multifactor productivity for the same period gained 1.5 percent. The industry experienced rapid growth in output and in both labor productivity and multifactor productivity between 1967 and 1973. A dramatic slowdown in all three measures occurred between 1973 and 1979, after which labor productivity rebounded somewhat. A major market for this industry's products is in retrofit and reconstruction activities, which have grown consistently in recent years, in part because of legislation at the Federal level. Exports represent a significant portion of the quantity demanded of this industry. Some establishments generate more than 35 percent of revenues from exports. Finally, a difficult challenge has been met by the refrigeration and heating equipment industry in that substitutes have had to be developed for a group of critical inputs, first chlorofluorocarbons, and then hydrochlorofluorocarbons. □

Footnotes

[1] This industry is designated as Standard Industrial Classification (SIC) 3585 by the Office of Management and Budget in the 1987 *Standard Industrial Classification Manual.* The full title of this industry is "Air-Conditioning and Warm Air Heating Equipment and Commercial and Industrial Refrigeration Equipment."

[2] In February 1992, the United States, responding to scientific findings,

announced that the phaseout of the production of CFC's would be accelerated and that these substances would be phased out by December 31, 1995—5 years earlier than mandated by the 1987 Montreal Protocol.

[3] Multifactor and labor productivity statistics in total manufacturing are calculated by the Division of Productivity Research, Bureau of Labor Statistics.

[4] Joe Jancsurak, "Expert Advice Without Consulting the Experts," *Appliance Manufacturer,* September 1991, pp. 58–61.

[5] Richard P. Perry, "CADD-An Engineer's Overview," *American Society of Heating Refrigeration and Air Conditioning Engineers Journal,* December 1982, pp. 34–35.

[6] Robert Mills, "Ford's Better Idea," *Computer-Aided Engineering,* October 1988, pp. 158–64.

[7] James F. Manji, "Automated Conveyor System...at Ford Plant," *Automation,* November 1990, pp. 62–66.

[8] "Controls Keep Quality Constant from Coils to Cabinets," *Appliance Manufacturer,* January 1991, p. 52.

[9] Debra Rosenberg, "Designing for Disassembly," *Technology Review,* November/December 1992, pp. 17–18.

[10] For a current source of the phaseout schedule, access online: http// www.epa.gov/docs/ozone/title6/phaseout/accfact.html. Also see *U.S. Industrial Outlook 1994* (U.S. Department of Commerce, January 1994).

[11] Ellen Brandt, "The Eradication of CFCs," *Chemical Engineering,* February 1993, pp. 25–26.

[12] *U.S. Industrial Outlook, 1994.*

[13] Ed Dooley, "World Demand for Chillers sets New Record, Huge U.S. Market Looms for Replacement Units," *Air Conditioning and Refrigeration Institute,* Apr. 4, 1996, On-line access: http://www.ari.org/pr/1996/ 960404.html.

[14] *Employment, Hours, and Earnings, United States, 1988–96,* BLS Bulletin 2481 (Bureau of Labor Statistics, August 1996); and *Employment, Hours, and Earnings, United States, 1909–94,* BLS Bulletin 2445 (Bureau of Labor Statistics, September 1994).

[15] *Employment, Hours, and Earnings, United States, 1988–96.*

[16] Industry sources.

[17] *1992 Census of Manufactures, Industry Series* (U.S. Department of Commerce, June 1995).

[18] Rogelio A. Maduro and Bob Holzkecht, "The $5 Trillion Mistake," *Machine Design,* Jan. 24, 1994, pp. 53–58.

[19] Kenneth J. Korane, "The Search for CFC Substitutes," *Machine Design,* May 24, 1990, pp. 95–100.

[20] "On January 1, 2003, production of HCFC-141b is banned ..."; "on January 1, 2030, production of all HCFCs is banned." As stated in sections 601–607 of the United States Clean Air Act.

[21] Simson Garfinkel, "The Coolest Sound," *Technology Review,* October 1994, pp. 17–19.

APPENDIX: Measurement of multifactor productivity

The following is a brief summary of the methods and data that underlie the multifactor productivity measure for the refrigeration and heating equipment industry. A technical note of more detail is available from the authors at the Office of Productivity and Technology, Bureau of Labor Statistics, Washington, DC 20212 (or call: (202) 606–5618).

Output. The output measure for the refrigeration and heating equipment industry is the weighted change in the deflated value of shipments of various types of equipment, as reported in the Censuses and Annual Surveys 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 1967, 1972, 1977, 1982, 1987, and 1992. The data and methodology are the same as those used in the previously published BLS output-per-hour series for this industry.

For productivity measures for individual industries, output 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 and nonproduction worker hours, both of which are calculated with BLS data (primarily from the Current Employment Statistics Survey). The labor input data are the same as those used in the previously published BLS output-per-hour series for this 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 productivity measurement, 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. For each type of asset, it is necessary to aggregate assets of different vintages. For BLS productivity measures generally, including those 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. These prices reflect the implicit rate of return to capital, the rate of depreciation, capital gains, and taxes. For an extensive discussion of the measurement of capital, see *Trends in Multifactor Productivity, 1948–81*, Bulletin 2178 (Bureau of Labor Statistics, 1983).

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 also are included. The data from which the estimates of 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 intra-industry transactions is removed from materials and fuels.

Annual estimates of the cost of services purchased from other business firms also are required for the measurement of multifactor productivity in a total output framework. 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 heating, air conditioning, and refrigeration equipment industry are derived by dividing an estimate of cost in current dollars for each input by the total cost of all inputs.