Productivity growth below average in the internal combustion engine industry

During 1967–82, output per hour increased at an annual rate of 2.1 percent; the impact of cyclical downturns in the economy, particularly in the later years, contributed to this lackluster growth

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Productivity, as measured by output per employee hour,[1] grew at an annual rate of 2.1 percent in the internal combustion engine industry from 1967 to 1982. The corresponding rate of increase was 2.4 percent for the average of all manufacturing industries.

The productivity gain in this industry resulted from a rate of growth in output of 4.2 percent, compared with the all-manufacturing average of 2.4 percent, and a 2.1-percent rate of increase in employee hours, compared with no growth in manufacturing sector hours. Productivity growth was aided by the introduction of new, more automatic equipment for machining engine components. However, this growth was modified by the impact of cyclical downturns in the economy on demand, resulting in sharp drops in industry production in several years and corresponding declines in productivity.

Establishments in this industry manufacture a wide variety of internal combustion engines ranging from small, single-cylinder gasoline engines used in such products as chain saws and lawnmowers to very large, multicylinder diesel engines used to power ships and locomotives and to generate electricity. Other products include outboard motors, largely used for propulsion of recreational boats, and diesel engines for automobiles and trucks.

Although markets are diverse, a majority tend to be affected by slowdowns in overall economic activity, leading to sharp declines in industry output, and corresponding declines in productivity. Conversely, in years of economic recovery, demand for internal combustion engines increases sharply, and the industry posts significant gains in output and, in turn, productivity.

Trends in productivity

The productivity trends in the industry can be divided into three distinct periods. (See table 1.) From 1967, when data first became available, to 1974, productivity grew at the high rate of 4.5 percent per year. During this period, output increased at the very high rate of 7.2 percent, while hours grew at a 2.6-percent rate. Productivity did not record any declines in this period. Although output dropped sharply in the recession year of 1970, hours fell even more and productivity posted a small gain. Output lagged somewhat in the recovery year of 1971, growing only 0.3 percent; however, it expanded sharply in 1972, up 17.5 percent. Productivity posted high gains in both years, growing 7.1 percent in 1971 and 7.5 percent in 1972.

In the 1974–78 period, productivity growth slowed to a rate of 3.8 percent per year. Despite acceleration in the rate of output gain to 8.6 percent per year, the growth in hours expanded to a 4.6-percent rate. There was 1 year of productivity decline during this period, the recession year of 1975, as output fell off sharply, and productivity dropped

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Table 1. Output per employee hour and related indexes in the internal combustion engine industry, 1967–82

[1977 = 100]

Year	Output per hour			Output	Employee hours		
	All employees	Production workers	Nonproduction workers		All employees	Production workers	Nonproduction workers
1967	70.3	68.8	75.1	51.4	73.1	74.7	68.4
1968	72.2	71.4	74.7	54.9	76.0	76.9	73.5
1969	75.4	74.6	77.8	65.6	87.0	87.9	84.3
1970	76.4	76.6	75.7	59.1	77.4	77.2	78.1
1971	81.8	82.5	79.9	59.3	72.5	71.9	74.2
1972	87.9	86.9	90.9	69.7	79.3	80.2	76.7
1973	91.0	88.9	97.8	79.8	87.7	89.8	81.6
1974	93.9	91.9	100.9	88.1	93.8	95.9	87.3
1975	86.7	89.5	79.1	73.6	84.9	82.2	93.1
1976	92.8	94.3	88.7	82.6	89.0	87.6	93.1
1977	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1978	105.4	106.0	103.8	114.3	108.4	107.8	110.1
1979	98.8	99.8	95.9	110.3	111.6	110.5	115.0
1980	94.8	98.5	85.0	94.8	100.0	96.2	111.5
1981	94.4	97.8	85.6	94.7	100.3	96.8	110.6
1982	87.0	99.2	63.5	71.4	82.1	72.0	112.4
	Average annual percent change[1]						
1967–82	2.1	2.6	0.6	4.2	2.1	1.5	3.6
1967–74	4.5	4.4	4.8	7.2	2.6	2.6	2.3
1974–78	3.8	4.0	3.0	8.6	4.6	4.4	5.5
1978–82	−4.2	−1.5	−10.4	−10.4	−6.4	−9.0	([2])

[1] Based on the least squares trends of the logarithms of the index numbers.
[2] Less than 0.05 percent.

a steep 7.7 percent. Output picked up significantly in the recovery year of 1976, gaining 12.2 percent, and expanded even more in 1977, growing 21.1 percent. Output continued to rise in 1978, up 14.3 percent. Productivity posted large gains in these years, increasing 7.0 percent in 1976, 7.8 percent in 1977, and 5.4 percent in 1978.

However, in the most recent period, 1978–82, productivity registered an annual average decline of 4.2 percent, with a decrease every year. During this period, output also declined every year, averaging −10.4 percent, while hours dropped at a rate of 6.4 percent. In the two recessions which occurred in this period, output dropped sharply and productivity recorded large declines. In the recession year of 1980, output fell 14.1 percent and hours decreased 10.4 percent resulting in a productivity falloff of 4.0 percent. Productivity registered its largest annual decline over the period in 1982, a recession year, dropping 7.8 percent as output fell 24.6 percent and hours decreased 18.1 percent.

Demand falls during 1978–82

The sharp slowdown in output and, in turn, productivity during the 1978–82 period can be attributed to a falloff in demand from most of the major markets for the industry's products. The period saw a large decline in construction activity and homebuilding. The number of new homes sold in 1982 dropped to about half of the 1978 level.[2] This decline affected the market for lawnmowers, garden tractors, snowblowers, and grass trimmers, resulting in an average annual falloff of 7.4 percent in the output of lawn and garden equipment. These items use small, gasoline-powered internal combustion engines, which are a major product of this industry. Output of construction equipment dropped at a rate of 14.0 percent over this period. The construction machinery industry uses midsized diesel and gasoline engines made in this industry. Demand from the agricultural equipment industry, which uses engines similar to those in construction machinery, also slowed as output of agricultural equipment fell at a rate of 7.6 percent during this period. The number of diesel truck engines produced also declined as the number of diesel-powered trucks manufactured declined from 1978 to 1982. Demand from the power generation and commercial shipbuilding markets also slowed, further reducing output of internal combustion engines. Conversely, demand for automobile diesel engines grew during most of the period, peaking in 1981. However, sales dropped in 1982, as the price advantage of diesel fuel versus gasoline was eroded.

Trends in employment and hours

Total employment in the internal combustion engine industry grew at a rate of 2.4 percent from 1967 to 1982. This rate of growth was significantly higher than the 0.2-percent rate of employment growth for the total manufacturing sector over the same period. Employment in this industry increased from 63,700 in 1967 to a high of 101,100 in 1979 and fell to 77,900 in 1982. Total employee hours grew at a rate of 2.1 percent, somewhat lower than the rate of employment gain. The number of production workers increased at an average rate of 1.9 percent during this period, growing from 47,500 in 1967 to a high of 74,200 in 1979 and falling to 51,600 in 1982. Nonproduction workers grew at the greater rate of 3.7 percent. The number of nonproduction workers in this industry increased significantly from 16,200 in 1967 to 26,900 in 1979 and fell slightly to 26,300 in 1982. The proportion of production workers to total employment fell from 74.6 percent in 1967 to 66.2 percent in 1982.

Average hourly earnings of production workers were significantly higher for the internal combustion engine industry than for the average of all manufacturing industries over the period measured. In 1967, these earnings were about 20 percent higher than the all-manufacturing average. By 1982, the gap had widened so that average hourly earnings were almost 40 percent higher than in manufacturing.

These higher earnings indicate that the skill levels of the workers in this industry are somewhat higher than in manufacturing as a whole. Data on occupations tend to corroborate this. Although occupational data that exactly match this industry are not available, data on occupations are available at a somewhat broader level of aggregation for the engines and turbines group.[3] Because employment in the internal combustion engine industry accounted for about two-thirds of this group in 1982, the aggregate data should be representative of the industry.

Craftworkers accounted for 21.4 percent of this group in

1982, compared with 18.6 percent in all manufacturing. Professional and technical workers made up a significantly higher proportion in this group (17.0 percent) than in total manufacturing (10.3 percent). However, although operatives accounted for a very large proportion of total employment in the engines and turbines group (36.6 percent), it was somewhat lower than the all-manufacturing average of 40.2 percent. Metalworking operatives were significantly greater at 17.8 percent for this group, compared with 6.8 percent for all manufacturing, and assemblers at 9.7 percent were higher than the all-manufacturing average of 6.9 percent. In the engine and turbine group, the professional and technical category increased from 13.0 percent in 1970[4] to 17.0 percent in 1982, while the operatives category fell from 40.6 to 36.6 percent over the same period.

Firms in the industry are large

Firms in the internal combustion engine industry tend to be large. The four biggest companies accounted for about 50 percent of the industry's value of shipments over the period studied. The average number of employees per establishment is much larger in this industry than the average for all manufacturing industries, 383 in 1977, compared with 53 for all manufacturing.

Engine manufacturers are concentrated in the north central portion of the United States, with large numbers of establishments located in Wisconsin, Illinois, and Michigan. California, however, has the most plants.

Above-average capital expenditures

The level of capital expenditures in the internal combustion engine industry has been high over the period studied. New capital expenditures per employee have been above the average for all manufacturing industries in most years from 1967 to 1981 and have never been significantly below average. In several years, new capital expenditures per employee have been significantly above the all-manufacturing average. In 1970, capital expenditures per employee were 60 percent above the manufacturing average. In 1973 and 1974, years of high output growth in the industry, capital expenditures per employee were almost double the all-manufacturing average. In 1981, capital expenditures per employee were more than 70 percent above the manufacturing average. Growth in capital expenditures has also been high. Capital expenditures per employee grew at a rate of 11.4 percent in this industry during 1967–81, compared with 10.6 percent for manufacturing as a whole. In the more recent period, 1978–81, capital expenditures per employee accelerated, growing at a rate almost twice as high as the all-manufacturing average, despite the output falloff in the industry.

Technological changes

As indicated, this industry produces many different engines ranging from very small, single-cylinder gasoline engines to very large, multicylinder diesel engines. Manufacturing techniques involve the production of engine parts and subassemblies and the assembly of parts into completed engines. Workflow, materials handling, and warehousing are critical functions in this industry. Changes in technology and innovations involve more advanced metalworking operations, introduction of new materials, combining of operations, automatic movement and positioning of work in process, and more automatic inspection of parts and testing of completed engines. As indicated by the recent acceleration in capital expenditures, many of the innovations in the industry were introduced in the more current period, in spite of the poor demand situation. This was done to increase plant efficiency, while employment was reduced, in anticipation of an expansion in demand, as well as because of increasing competition from imports.[5]

Typically, the production of engines begins by machining rough castings of engine blocks, crankshafts, gear blanks, and other parts using a wide range of metalworking techniques. The castings are in some cases produced in-house but, as with many other parts, are often purchased from outside suppliers. The finished parts, along with other vendor-supplied items, are then brought together for final assembly.

The casting of parts (either in gray iron, steel, or aluminum) ranges from highly automated to relatively labor-intensive. In plants which manufacture high volume, small horsepower engines, the casting of parts has been to a large degree automated using computer control and robots. Other establishments which produce low volume parts have not been able to automate the casting process so intensively.

After casting, many parts such as gear blanks and crankshafts are heat treated or carburized. In this process, the engine parts are baked at a high temperature in an atmosphere of carbon dioxide in order to chemically alter the metal to the desired characteristics. Because different parts require different characteristics, the process variables (that is, time, temperature, pressure of gas) are sometimes monitored by computer.

Transfer lines are commonly being used for machining large volume components in the industry. Typically, engine block machining is now done on transfer lines. The lines move the rough castings automatically to and from machining stations where, for example, cylinder walls are ground to the correct tolerances, coolant and lubrication channels are bored, and bolt holes are drilled and tapped. Workers are required at each machining station only to perform initial tool setup, monitor performance, and provide maintenance. In some cases, loading and unloading of work in process and tool changing, formerly done manually, are done automatically. In addition, automatic testing and inspection equipment has been incorporated on transfer lines, aiding product quality. The installation of automatic transfer lines for block machining has reduced the direct labor involved in these operations significantly.

An innovation that has recently been introduced for the manufacture of parts is computer-directed flexible machining centers. Several of these flexible or multiple function machining centers can be operated under the control of a central computer. Work in process moves from machine to machine by automatic conveyor line or on dollies powered by in-floor drive systems. These machining centers are flexible enough so that if one is off-line for repair or maintenance another center can take over its functions. Typically, these machining centers have worn or broken tool alert capability and, in some cases, automatic tool change capacity. Unlike the automatic transfer lines, workers tending these flexible machining systems are required only to perform maintenance. Because of the flexibility built into these lines, changeovers to the production of different items can be expedited. Shorter production runs then become more practical because the equipment is not down for lengthy manual tool change operations.[6]

Numerically controlled machine tools are in use throughout the industry. They are utilized mainly for production of low and medium volume parts. Computerized numerical control machining centers have also recently been introduced for the production of engine components.

Computer-assisted design is being used by many firms in the industry for engine and component design as well as for making changes in engine configurations to meet customers' specifications. Computer-assisted manufacturing is in more limited use than computer-assisted design in the industry and is involved mainly in the operation of machining centers for individual components rather than control of large-scale manufacturing operations. Computer-assisted manufacturing is also used by some firms to make tools and dies required for machining operations.

The final assembly of engines in this industry tends not to be highly automated, compared with automobile engine assembly. There are automobile engine plants where complete units are built with very little direct manual labor.[7] Although there are some exceptions,[8] this is generally not the case in the industry under study. Typically, parts move by conveyor to work stations where the employees assemble the engines with the assistance of a variety of powered equipment and handtools. Assembled engines are then started in order to make final adjustments and to verify performance. Often, particularly for the larger engines, the completed units are run under load while being monitored by computer. Some of the more expensive diesel engines are partially disassembled and visually inspected after the running test.

During the last 10 years, robots have increasingly been employed in the production of engines. Their use to date has been principally limited to such applications as metal casting, heat treating, and painting operations where it was particularly desirable to remove workers from these hazardous areas. Highly repetitive jobs, such as the insertion of valve seats in engine blocks, have also been robotized. Additionally, robots have been used in the production of investment casting molds. In this application it was found that robots could more consistently produce higher quality molds than the workers they replaced.[9]

Manufacture of the very large diesel engines used for marine or power generation purposes tends to be significantly different than the manufacture of the small- and medium-sized engines. The blocks of these engines are not machined from a solid casting but rather are made from steel plates welded together. These units are built in one place and parts are brought to it, compared with assembly line manufacture of the smaller engines. Machining of very large parts to extremely close tolerances is important in the manufacture of these units. Therefore, innovations include numerically controlled flame-cutters and computer-controlled flexible machining centers to finish the flat steel shapes to the correct dimensions. Numerically controlled large machine tools and computer machining centers are important technological advances in the production of these large engines because of the small runs of complex parts such as pistons, cylinder liners, and the close tolerances required for manufacture.

An important innovation is the introduction of computerized high-rise warehouses for raw materials and incoming parts as well as for completed parts and engines. These automated warehouse systems are utilized by many firms in the industry and have resulted in significant labor savings.

Outlook

In recent years, the industry has experienced poor demand, with output in 1982 significantly below its peak in 1978. Incomplete data indicate that in 1983 demand for products using internal combustion engines was mixed and the output and productivity situation was uncertain. However, by 1984 demand began to increase from many of the industry's markets leading to anticipated gains in output and productivity.

Recently, the industry has increasingly been affected by the pressure of growing imports. This is especially true for such items as outboard motors and low horsepower gasoline engines, which have not faced significant import competition in the past. In an effort to compete with imports, firms in the industry have accelerated the introduction of new technology and have shifted attention to more efficient production operations and management techniques. New plants using the most modern production technology have been opened. Older plants have been significantly modernized. Therefore, the industry's ability to increase productivity has been enhanced. However, the impact of cyclical changes in the economy can be expected to continue to be a major determinant of demand for the industry's products, resulting in wide swings in output. In turn, productivity changes in this industry will continue to be affected by these cyclical changes. □

———*FOOTNOTES*———

[1] The internal combustion engines, n.e.c., industry is classified as SIC 3519 in the *Standard Industrial Classification Manual 1972* and its 1977 supplement, issued by the U.S. Office of Management and Budget. This industry includes establishments primarily engaged in manufacturing diesel, semidiesel, or other internal combustion engines, not elsewhere classified, for stationary, marine, traction, and other uses. Aircraft engines, automotive engines (except diesel), and engine generator sets are not included.

[2] *Construction Report, New One-Family Houses Sold and For Sale, March 1984*, U.S. Department of Commerce, c25–84–3, May 1984, p. 3.

[3] "BLS Industry-Occupational Employment Matrix, 1982, 1995 Alternatives," pp. 154–65, 373–78.

[4] *The National Industry-Occupation Employment Matrix, 1970, 1978, and Projected 1990*, Bulletin 2086 (Bureau of Labor Statistics, 1981), p. 74.

[5] Information obtained from industry representatives.

[6] See "Flexible Manufacturing Takes Shape," *Automotive Industries*, January 1983, pp. 17–20; see also "Microprocessor Controlled Engine Transfer Line," *Diesel Progress, North American*, December 1982, pp. 6–7; and "Turning Cells Boost Gear Blank Output," *Production Engineering*, August 1984, pp. 60C–60F.

[7] See Michael K. McCann, "Another Step Towards the Automated Plant," *Automotive Industries*, November 1981, pp. 61–63.

[8] See "Automatic Assembly Increases Efficiency, Output," *Manufacturing Engineering*, October 1980, p. 29.

[9] See Joseph F. Engelberger, *Robotics in Practice*, American Management Associations, 1980, pp. 181–88.

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.

Because data on physical quantities are not reported for the entire internal combustion engine industry, real output was estimated by a deflated value technique. Changes in price levels were removed from current-dollar values of production by means of appropriate price indexes at various levels of subaggregation for the variety of products in the group. To combine segments of the output index into a total output measure, employee hour weights relating to the individual segments were used, resulting in a final output index that is conceptually close to the preferred output measure.

Employment and employee hour indexes were derived from data published by the Bureau of the Census. Employees and employee hours are each 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. The indexes do not measure the specific contribution of labor or capital, or any other single factor. Rather, they reflect the joint effect of factors such 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.

The average annual rates of change presented in the text are based on the linear least squares trend of the logarithms of the index numbers. Extensions of the indexes appear annually in the BLS Bulletin, *Productivity Measures for Selected Industries*. A technical note describing the methods used to develop the indexes is available from the Division of Industry Productivity and Technology Studies, Bureau of Labor Statistics.