The mining machinery industry: labor productivity trends, 1972–84

The average annual rate of productivity growth in this industry was substantially below that for all manufacturing; the industry has felt the effects of falling coal prices and fuel shortages over the past 10 to 15 years

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Productivity, as measured by output per employee hour, in the mining machinery industry declined at an average annual rate of 1.2 percent from 1972 to 1984.[1] (See table 1.) This trend was substantially below the rate for the manufacturing sector, which grew at a rate of 2.0 percent during this period. Since 1972, the mining machinery industry has introduced new technology and work methods. However, major shifts in demand for coal have created wide variability in capacity utilization rates. Periods of both strained and excess supplies of coal have resulted in low productivity in mining machinery.

The decline in productivity was accompanied by a drop in output of 3.3 percent and a decline in employee hours of 2.2 percent. Although the productivity trend was negative, there was significant year-to-year variation. Many of the annual movements were associated with changes in output. In 5 of the 6 years that output advanced, there were increases in productivity. Similarly, productivity declined in 4 of the 6 years that output fell.

From 1972 to 1974, productivity in the mining machinery industry advanced nearly 12 percent, as output surged 35 percent. Over the following 2 years, productivity declined by 9 percent as employment in the industry increased substantially. From 1972 to 1976, employee hours increased more than 50 percent.

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The industry's output rose in the early 1970's in response to increased energy-related demand for coal. From 1971 to 1975, coal production increased more than 17 percent. Purchases of mining equipment grew significantly during this period, leading to high levels of capacity utilization. However, by 1975, these rapid increases in demand also dampened productivity advances as mining companies became overbooked and capacity became strained.[2]

During the 1977–82 period, productivity fell at an average annual rate of 0.9 percent; both output and employee hours dropped. The industry was particularly hard hit by the economic downturn which occurred during this period.

The 1981–82 recession brought a substantial decline in the demand for many metals and minerals during 1982. The low level of construction activity and the decline in production of durable goods—such as automobiles, construction machinery, and electrical appliances—significantly reduced the demand for steel, copper, aluminum, and other metals. As many U.S. mines curtailed or halted production, the year was marked, in particular, by a slowdown in the demand for mineral processing equipment such as flotation machines and crushers. Although there was expanding coal production in 1982 which served to offset some of the decline in the demand for equipment used in other types of mines, it was not enough to prevent a severe drop in output and a decline in employee hours. This resulted in a sharp decline in productivity.

The recovery during the 1983–84 period was strong

Table 1. Productivity and related indexes for mining machinery, 1972–84
[1977=100]

Year	Output per employee hour			Output	Employee hours		
	All employees	Production workers	Nonproduction workers		All employees	Production workers	Nonproduction workers
1972	103.3	100.9	108.1	69.6	67.4	69.0	64.4
1973	108.7	104.5	117.8	78.7	72.4	75.3	66.8
1974	115.2	108.3	131.7	93.8	81.4	86.6	71.2
1975	111.5	104.8	127.4	105.6	94.7	100.8	82.9
1976	95.1	90.3	105.9	98.7	103.8	109.3	93.2
1977	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1978	93.9	96.0	90.0	90.9	96.8	94.7	101.0
1979	95.6	97.7	91.7	90.3	94.5	92.4	98.5
1980	98.6	102.8	91.5	92.4	93.7	89.9	101.0
1981	97.8	102.5	89.7	87.5	89.5	85.4	97.6
1982	91.0	104.4	73.1	68.1	74.8	65.2	93.2
1983	96.1	115.7	72.5	49.5	51.5	42.8	68.3
1984	98.9	110.7	81.9	51.9	52.5	46.9	63.4
	Average annual rates of change (percent)						
1972–84	-1.2	0.6	-4.2	-3.3	-2.2	-3.9	1.0
1979–84	0.1	2.9	-4.1	-13.0	-13.1	-15.5	-9.3

enough to turn around the productivity decline, leading to a rise of 4.3 percent. Although output continued to drop in 1983, an even steeper drop in employee hours resulted in a productivity gain of nearly 6 percent. In 1984, both output and employee hours reversed their long-term rates of decline. Productivity advanced 2.9 percent as output rose 4.8 percent and employee hours increased 1.9 percent. Growth of U.S. and foreign coal mine production in 1984 was a major stimulant for sales of mining machinery, particularly continuous miners, shuttle cars, roof bolters, and longwall mining systems. Increased use of coal in electric power generation, which now accounts for 50 percent of all fuel used, has helped the demand for mining equipment.[3]

Employment and plant size

Over the 1972–84 period, employment in the mining machinery industry decreased more than 20 percent, falling at an average annual rate of 1.8 percent. For the first 4 years of the period, employment increased steadily, rising from 21,300 employees in 1972 and peaking at 31,900 in 1976. The 1976–84 period evidenced employment declines in each year to 1983, with the number of employees dropping to 16,900 and remaining unchanged in 1984.

According to the Census of Manufactures, there were 240 establishments in the mining machinery industry in 1972, and 369 establishments in 1982, an increase of 54 percent (or 129 establishments). The average number of employees per establishment decreased from 89 in 1972 to 66 in 1982, a decline of 26 percent. Production workers accounted for 67 percent of employment in 1972 and 58 percent in 1982.

Employment of nonproduction workers remained unchanged between 1972 and 1984, even as their share of the total industry work force rose. In the earlier 1972–80 period, employment of nonproduction workers increased from 7,000 to slightly more than 11,000—an average annual increase of 6.8 percent. However, since 1980, the total number of nonproduction workers has declined to its 1972 level. Higher relative growth rates among nonproduction workers reflect industry needs for computer-related technical support personnel, as well as the increased emphasis on research and development activities. Further escalation of nonproduction worker employment is anticipated, particularly in the categories of computerized production, planning, technical help, and scheduling.

The establishments which produce mining machinery vary in size but, generally, are rather small and are geographically concentrated in Pennsylvania, Ohio, West Virgina, and Virginia. No one manufacturer makes a complete line of products. Because the availability of parts and service is an important selling factor, most major manufacturers have sales and service offices in all major mining areas. In 1982, more than 52 percent of the 369 establishments in the industry employed fewer than 20 persons and accounted for only 5 percent of industry value of shipments. In contrast, larger establishments with more than 100 employees accounted for 15 percent of all establishments and 74 percent of sales. Since 1972, there has been a slight increase in the percentage of establishments with fewer than 20 persons. However, the percentage of industry value of shipments attributed to these smaller establishments remains unchanged from 1972, at 5 percent.

Earnings. Average hourly earnings in the mining machinery industry have remained higher than those in all manufacturing. In 1972, average hourly earnings in the industry were $4.22, compared with $3.82 for all manufacturing. In the 1972–77 period, the industry's average hourly earnings rose about 52 percent to $6.42, and by 1984, had risen to $11.32—an increase of 76 percent from 1977.[4] This is significantly higher than the average for all manufacturing, which was up to $5.68 in 1977 and $9.19 in 1984.

Mining equipment

The term "mining machinery" refers to a line of equipment which is specially designed for the underground mining of ores and coal. The major types of extraction equipment are percussion-type rock drills, rock drilling bits, rotary face drills, augers, blast hole drills, continuous miners, roof bolting machines, cutting machines, longwall mining machinery, and supports. Haulage of the mined ore to processors is in shuttle cars, loader hauler-dumper vehicles, mine cars or belt conveyors. Depending on conditions and applications, mining machinery uses electric, diesel, or battery power. In addition, hydraulic fluid power is replacing compressed air power in some machinery to reduce noise and improve efficiency.[5]

Coal and ore extraction methods—continuous mining, conventional mining, and longwall mining—use different types of equipment to do the actual mining. The choice of the system used depends on the geology of the seam and the amount of initial capital the mine operator wishes to invest.

The continuous miner is of major importance in underground coal mining. In one operation, the continuous miner cuts or rips the coal from the working face and loads it into shuttle cars or onto a conveyor haulage system. From its inception, the continuous miner processed much greater amounts of coal than the machinery it superseded.[6] It eliminates the need for coal cutters, face drills, blasting equipment, loaders, and the mining crews needed to operate these machines. Throughout the world, the room and pillar method of coal mining is widely accepted; and the American-made continuous miner remains very popular.[7] Among the labor-saving machines being introduced is a new generation continuous miner which can be set to mine coal in an automated mode, and has the ability to simultaneously mine coal and bolt the roof.

In conventional mining, coal is blasted rather than cut from the working face, utilizing mechanical extraction procedures such as undercutting the face, drilling holes for explosives, and loading the coal into shuttle cars with gathering arm-type loading machines.[8] Once America's primary coal mining method, conventional miners cut less than 25 percent of the coal mined underground today. Small mining companies are the primary users of conventional mining equipment, which is easier to repair and has less downtime than continuous miners. Only one company in the United States offers a full line of conventional equipment.[9]

Longwall mining machines are increasingly being used in U.S. underground coal mines. Unlike a continuous miner, which has a cutting width of about 10 feet, the longwall machine is guided across a seam several hundred feet wide. As it mines across the face, the coal drops onto a face conveyor at the base of the longwall system. The mine roof above the machine is temporarily supported by hydraulically-operated self-advancing roof supports. As the longwall cutter advances, the mine roof is allowed to cave in behind the machine while, at each end of the face, haulage and air passageways are maintained.[10] Considered to be more efficient than the room and pillar system, the longwall system increases mine safety by eliminating the need for explosives. It also requires a much higher initial investment, however; a complete longwall system often costs about $5 million.[11] Longwall systems, more commonly used in Europe, are said to be best for large, relatively level seams. Although longwall mining systems were almost nonexistent in the United States prior to 1965, they now produce about 10 percent of all domestic coal mined underground.[12]

Extraction, haulage, and roof support systems are unit operations common to both coal and hardrock mines. However, underground hardrock mining systems and equipment are quite different from those used in coal mines. Underground hardrock mines use a wide variety of equipment types—the most common of which include jumbo-mounted percussion drills and handheld rock drills. The self-propelled jumbo vehicle supports one to three hydraulically powered booms which position the drill against the rock face. Rapidly oscillating pistons, driven by pneumatic or hydraulic power, generate a series of impulsive blows, causing a stress wave to move through the drill bit into the rock, which shatters under the tungsten carbide cutting edges of the bit. Handheld hardrock drills are used especially in tight quarters where jumbo-mounted drills cannot fit. Handheld drills are smaller and less powerful than the jumbos, but the operating principles are the same. Metallurgical improvements in the 20th century have permitted the development of high-strength rock drill components that impart tremendous amounts of energy to the rock face.[13]

Other important products of the mining machinery industry include beneficiation (ore-processing) and mineral pulverizing equipment. These products are used to transform the mineral ore into a usable product by separating out the mined minerals and metals, and include crushers, rod and ball mills, classifiers, screens, feeders, grinding mills, flotation devices, centrifuges, and dryers. Preparation plants contain equipment that performs one of three primary functions: crushing (size reduction), screening (size separation), and dewatering. Additionally, many plants contain equipment that separates valuable constituents (coal or ores) from waste material through differences in their densities, physical properties, chemical properties, or magnetic properties or through a combination of these.

Mine transport equipment includes hoists, mine cars, belt conveyors, and locomotives that haul the coal and ores out of the mines. When electrical power was introduced into the mines, personnel haulage vehicles were developed. Typical of these is the rail-mounted "mantrip" or "portal bus" that carries workers from the mine portal to the face areas.[14]

Capital expenditures

Reduced levels of capital expenditures have accompanied the productivity decline in the mining machinery industry. Measured in constant dollars, capital expenditures fell 8 percent from $13.4 million in 1972 to $12.3 million in

1984. The real annual rate of growth in new capital expenditures per employee averaged about 1 percent, a rate comparable to that of all manufacturing industries. However, in 1984, the level of capital expenditures per employee in the mining machinery industry was less than one-half of the level for all manufacturing industries. In 1982, the latest year for which data are available, the industry allocated 73 percent of capital expenditures to the purchase of new machinery and equipment and used the remainder for new structures and plant additions.

Mining machinery is generally sold to mine operators. Occasionally, machinery may also be sold to equipment leasing companies which, in turn, lease them to operators who are too small to purchase the equipment themselves. Because mining requires major capital investment, and because of rising costs of new machinery (a continuous miner costs from about $510,000 to $525,000; a loader costs about $300,000; and a face drill costs between $45,000 and $60,000),[15] mines often rely on service centers to extend the life of their machines as an alternative to purchasing new equipment. Consequently, the demand for repair and replacement parts has become a major market for the U.S. mining industry.[16] Parts and attachments for mining machinery and equipment accounted for 42 percent of the industry value of shipments in 1972 and 45 percent of the industry value of shipments in 1982.

Manufacturers of new equipment, as well as independent repair firms, are expanding their rebuilding facilities in major mining areas, and service centers have become major outlets for repair and replacement parts. Sales of new mining machines often depend on convenient accessibility to the manufacturer's parts centers and on prompt repair service provided by the manufacturer.

Advances in technology

The mining machinery industry has introduced some new techniques and work methods which have not yet been reflected in overall productivity improvements. New technological developments in the industry have been generated by research efforts conducted by the mining industry, equipment manufacturers, the academic world, and government agencies. These efforts continue to improve mining equipment. Current research in the production of mining machinery is aimed at increasing equipment flexibility, with safety continuing to receive substantial emphasis. For instance, longwall mining machines are operated with hydraulic roof supports to protect both miners and equipment from roof falls. These efforts to improve mining equipment have been successful but have resulted in higher costs and may have retarded productivity growth.

The gradual advent of numerical control in the mid-1960's has been an offsetting factor to the general decline in industry productivity. Manufacture of the large, complicated units which comprise an important segment of the industry involves the assembly of parts—many of them machined by numerical control. Numerical control involves the use of a tape-fed controlling mechanism to operate the machine tools used in the manufacturing process. A major advantage of numerically controlled manufacturing procedures is that idle time in the factory is markedly reduced. Numerical control results in more accurate work, better repeatability of operations, higher speed, and a reduction in tool setup time. Numerical control also makes possible a substantial reduction in labor requirements and more effective machine utilization.

Although not widely diffused in the industry, some plants have introduced into their operations computer assisted design (CAD) and computer assisted manufacturing (CAM) systems. The CAD/CAM systems have been termed a "marrying of engineering and manufacturing." They are particularly well-suited to improving efficiency in the mining machinery industry where there are frequent demands for equipment design modifications.

In addition, some manufacturers of mining equipment are phasing out the traditional "functional grouping" of machine tools used in the production process. Direct-labor employees will be relocated to "work cells"—work stations at which are grouped the various machine tools to be used in all stages of production. This contrasts with the more conventional functional grouping where tools are grouped according to their specialized use, with the part being transferred from one work area to another. Use of the work cell concept over the functional grouping method results in both reduced handling and improved workflow of finished products. Employees, who are highly specialized and have, in the past, operated one machine tool, will now have their skills upgraded to run several pieces and will, in effect, be responsible for all phases of production from beginning to end. Introduced in the mid-1970's, the work cell concept has been well received in this industry where its use has accelerated in the past 2 years.

This rethinking of work assignments and restructuring of the workplace has improved product quality and reduced in-process inspection and setup time. It has been instrumental in achieving control over inventories of parts and materials. Manufacturers are undergoing a whole new change of focus in their material movement operations, hoping to enhance output and productivity. Under traditional methods, the amount of time spent actually working on an individual part was only 5 percent. During the remaining time, the part was held for further processing or was transported from one work area to another.[17]

Outlook

Despite the use of some advanced technology in the workplace, the mining machinery industry has still suffered numerous declines in productivity since the mid-1970's. Output declines since 1977, brought about by reduced demand for equipment, have overshadowed any improved production methods used by equipment manufacturers. A highly competitive business and dependent almost exclusively on the coal industry as its main customer, the mining machinery industry has felt not only the effects of falling coal prices, but also the repercussion of fuel shortages and various energy crises over the past 10 to 15 years. Currently, the coal mining industry is faced with excess capacity which has resulted in reduced demand for coal mining machinery.[18] The general decline over the years of U.S. mining has resulted in mining companies purchasing repair and replacement parts, opting to retrofit and rebuild existing machinery rather than purchase new equipment.

Computer-integrated manufacturing that allows a central computer to operate shop-floor machines is only now being introduced in some of the factories that produce mining machinery. In 1985, a large plant was planning to use a direct numerical control host computer, complemented by the use of computer numerical controls (CNC). Work cells and various machine tools in the plant are outfitted with CNC's featuring microprocessor controls. An example of CNC use is the machining center with maneuverable turrets on which are mounted a number of cutting tools. This one computer-directed machine, manned by one person, is capable of performing many different cutting operations on a workpiece, eliminating the need to transfer the piece to numerous individually manned cutting machines. One such machining center can replace multiple conventional machines and their operators without loss of output. It also assures better quality control, needs less floor space and handling equipment, and requires lower in-process inventory. Because the CNC has its own control and its own computer, it can correct onsite production problems quickly, thus reducing the amount of "downtime" formerly experienced in the manufacturing process.

Future improvements in industry productivity will, in large part, depend on increases in demand for the industry's output, the ability to introduce the aforementioned technological advances, and wider diffusion of CAD/CAM systems. In addition, mining machinery companies hope to increase demand for equipment used in the construction of tunnels for underground subway systems and public utilities. Introduction of diesel equipment should also aid productivity growth. Because diesels require fewer parts, the manufacture of such equipment would result in lower unit labor requirements. Also in the future, more attention will be focused on ocean mining. Specialized mining equipment is now being developed to recover metal and mineral nodules from the ocean floor. However, it appears that, in the foreseeable future, nodule mining would most likely not be economical, and will not take place without significant financial incentives.[19] □

——FOOTNOTES——

[1] Average annual rates of change are based on the linear least squares trend of the logarithms of the index numbers. The mining machinery and equipment industry is designated industry 3532 in the *Standard Industrial Classification Manual, 1972 Edition*, issued by the Office of Management and Budget. The industry comprises establishments primarily engaged in the manufacture of heavy machinery and equipment used by the mining industries, such as coal breakers, mine cars, mineral cleaning machinery, concentration machinery, core drills, coal cutters, portable rock drills, and rock crushing machinery. The mining machinery industry excludes establishments primarily engaged in the manufacture of well drilling machinery and of coal and ore conveyors, which are classified in industries 3533 and 3535.

[2] Industry spokesperson during 1985 tour of manufacturing facilities.

[3] *U.S. Industrial Outlook* (U.S. Department of Commerce, 1985), pp. 23-3—23-6.

[4] Industry earnings figures are based on employee hour data from the Bureau of Labor Statistics.

[5] *U.S. Industrial Outlook* (U.S. Department of Commerce, 1980), pp. 213–15.

[6] Stanley Suboleski, "Boost Your Productivity by Adding Continuous Miners," *Coal Age*, March 1975, p. 78.

[7] *American Mining Congress Journal*, Mar. 27, 1985, pp. 12–14.

[8] Bureau of Mines Information Circular 9004 (U.S. Department of the Interior, 1985), pp. 9–10.

[9] David Brezovec, "Conventional Output Falls in U.S.," *Coal Age*, May 1982, p. 82.

[10] *U.S. Industrial Outlook* (U.S. Department of Commerce, 1980), pp. 213–15.

[11] *U.S. Industrial Outlook* (U.S. Department of Commerce, 1982), pp. 199–201.

[12] Bureau of Mines Information Circular 9004, p. 10.

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

[14] *Ibid.*, p. 11.

[15] David Brezovec, "Conventional Output Falls in U.S.," *Coal Age*, May 1982, p. 86.

[16] *U.S. Industrial Outlook* (U.S. Department of Commerce, 1982), pp. 199–201.

[17] Industry spokesperson during 1985 tour of manufacturing facilities.

[18] Industry spokesperson.

[19] *Equipment Management*, April 1984, p. 65. See also Bureau of Mines Information Circular 9015 (U.S. Department of the Interior, 1985), pp. 1–15.

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 of 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 adequate physical quantity data, the output index for this industry was constructed by a deflated value technique. The value of shipments of the various product classes was adjusted for price changes by appropriate Producer Price Indexes and Industry Sector Price Indexes to derive real output measures. These, in turn, were combined with employee hour weights to derive the overall output measure. The result is 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 do not measure any specific contributions, such as that of labor or capital. 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.