Productivity growth average in farm machinery manufacturing

Productivity gains, aided by new technology, especially computers, but moderated by cyclical downturns, averaged 2.6 percent a year over the 1958–80 period

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Productivity, as measured by output per employee hour, in farm machinery manufacturing[1] was about the same as the average for all manufacturing industries over the 1958–80 period. Growth was aided by numerically controlled machine tools, automatic welding, computerized manufacturing, industrial robots, and computerized automatic warehouses, but was partially offset by sharp declines in demand. Almost every decline in productivity during the period studied can be associated with a drop in output, which, in turn, usually coincides with downturns in the economy. During the 22-year period, productivity in the farm machinery industry grew at a rate of 2.6 percent a year, compared with 2.7 percent per year for all manufacturing industries; 1.9 percent for construction machinery, an industry which uses similar manufacturing techniques; and 3.2 percent for motor vehicles, another similar industry.

Output, productivity follow farm income

Productivity growth in the farm machinery industry can be divided into three distinct periods. From 1958–65, productivity grew at an annual rate of 1.7 percent; from 1965–74, it accelerated to a 3.3-percent rate; and from 1974–80, slowed to 0.2 percent. (See table 1.) The higher rate of gain during the 1965–74 period can be associated with years of very high output, fueled by dramatic increases in farm income.

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Productivity changes in the farm machinery industry are closely tied to output changes over the short term. Demand for farm machinery is based on a number of interrelated factors. A major factor is the overall state of the economy. However, an even more directly related factor is farm income. Changes in the output of farm machinery closely parallel changes in farm income. When farm income is up, farmers tend to purchase new equipment. Among the determinants of income are crop size, both actual and anticipated in the near future, and farm prices. Crop size is, of course, affected by a number of variables, including the weather, farm prices, government policies, and the worldwide food supply. Other important factors affecting the production of farm machinery are farmers' costs, such as for loans, new machinery, land, fertilizers, and pesticides, as well as age and condition of existing equipment and imports and exports of farm equipment.

When income is low and prospects appear poor, farmers tend to make do by repairing, rather than replacing, existing equipment. Conversely, when income is growing and prospects for further expansion of profits appear good, they tend to purchase new, more productive equipment. Demand for machinery increases significantly during these expansive periods, as does productivity.

The impact of the numerous variables affecting demand changes rapidly over time; therefore, output of farm machinery shows wide swings. Productivity, however, moves in a less volatile manner. For example, output grew by 6.3 percent between 1958 and 1959, but

then dropped precipitously in 1960, a recession year, falling 18.3 percent. Concomitantly, productivity had no growth in 1959 and dropped sharply, by 7.1 percent, in 1960. In 1966, output increased substantially, up 19.4 percent, then declined for 4 consecutive years, one of which was the recession year of 1970. Following output, productivity also grew substantially in 1966, up 6.2 percent, and then dropped sharply, averaging 0.8 percent from 1967 to 1970.

The early 1970's were a period of high output growth, with gains of 16.5 percent in 1972, 21.3 percent in 1973, and 14.3 percent in 1974. This strong growth can be attributed to a sharp increase in farm income resulting, in part, from large exports of farm products, including sales of grain to Russia. Productivity recorded its largest advances during this period, with increases of 8.9 percent in 1971, 9.3 percent in 1972, 5.2 percent in 1973, and 3.6 percent in 1974.

In the more recent period—1980, a recession year—output dropped 15.1 percent, as farm income declined precipitously. In turn, productivity declined 6.7 percent.

A factor affecting output over the long term is the continuously increasing size of farms. The average farm in the United States has shown a significant increase in size, growing about 40 percent in acreage over the period studied.[2] This created a need for an increase in the physical dimensions and horsepower of farm machinery. To cope with the growing acreage, farmers purchased larger, more powerful equipment, rather than increasing their labor force. For example, the average horsepower (PTO) rating of tractors was 106 in 1980, compared with 67 in 1958. Demand for farm equipment has also been enhanced by such equipment as 4-wheel drive tractors, which allow farming in previously marginal areas, and such amenities as air conditioning and stereo radio and cassette equipment in the cabs of the larger units.

Demand for larger, more productive farm machinery has been one factor leading to the industry's long-term growth rate in output of 4.2 percent, somewhat higher than the 3.8 percent for the total manufacturing sector. Highly advanced farm equipment is one of many reasons that productivity has been significantly higher in the farm sector than in the nonfarm sector.

Plants located in Farm Belt

The farm machinery manufacturing industry has paralleled the growth of agriculture in the United States. Some of the larger firms can trace their origins to the development of horse drawn harvesting equipment in the early 1800's. Therefore, farm machinery manufacturing is a mature industry, producing a variety of equipment for both U.S. markets and export.

There were 2,148 establishments in the farm machinery industry as of 1977, a significant increase over the 1,949 establishments reported in 1958. The number of employees per establishment has remained fairly constant, dropping slightly from 74 in 1958 to 70 in 1977 (the average for all manufacturing industries was 53).

Table 1. Output per employee hour and related indexes in the farm machinery equipment industry, 1958–80

[1977=100]

Year	Output per hour			Output	Employee hours		
	All employees	Production workers	Nonproduction workers		All employees	Production workers	Nonproduction workers
1958	65.1	64.9	65.5	49.4	75.9	76.1	75.4
1959	65.1	63.4	70.3	52.5	80.7	82.8	74.7
1960	60.5	61.3	58.6	42.9	70.9	70.0	73.2
1961	62.9	61.3	67.7	45.7	72.7	74.5	67.5
1962	65.1	65.1	64.8	48.8	75.0	75.0	75.3
1963	66.6	64.3	74.3	53.7	80.6	83.5	72.3
1964	70.2	66.9	82.0	60.1	85.6	89.9	73.3
1965	72.2	68.6	84.8	64.0	88.6	93.3	75.5
1966	76.7	72.3	92.7	76.4	99.6	105.6	82.4
1967	76.8	73.3	88.8	73.6	95.8	100.4	82.9
1968	76.7	75.0	82.1	70.8	92.3	94.4	86.2
1969	73.8	73.2	75.9	65.8	89.1	89.9	86.7
1970	75.7	75.2	77.3	65.1	86.0	86.6	84.2
1971	82.4	83.0	81.0	66.2	80.3	79.8	81.7
1972	90.1	87.0	99.9	77.1	85.6	88.6	77.2
1973	94.8	90.7	109.2	93.5	98.6	103.1	85.6
1974	98.2	92.6	118.3	106.9	108.9	115.4	90.4
1975	97.7	95.3	105.2	100.0	102.4	104.9	95.1
1976	101.1	100.5	103.1	98.9	97.8	98.4	95.9
1977	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1978	100.8	100.1	103.1	95.6	94.8	95.5	92.7
1979	103.2	101.7	108.0	114.7	111.1	112.8	106.2
1980	96.3	99.6	88.1	97.4	101.1	97.8	110.6
	Average annual rates of change (percent)[1]						
1958–80	2.6	2.7	2.4	4.2	1.5	1.5	1.8
1958–65	1.7	1.0	3.9	3.9	2.2	2.9	([2])
1965–74	3.3	3.4	2.9	3.7	0.5	0.4	0.8
1974–80	0.2	1.2	−2.9	−0.1	−0.3	−1.4	2.9

[1] Based on the least squares trend of the logarithms of the index numbers.
[2] Rate of change is less than 0.05 percent.

The industry has a few very large firms with numerous establishments making a variety of equipment—tractors, combines, and other harvesting equipment, crop sprayers, plows, harrows, planters, cultivators, hay balers, and fertilizing equipment. These firms are highly integrated and manufacture many of the parts that are assembled into the final products, including both gasoline and diesel engines, as well as replacement parts for the older units in operation. The large firms generally produce the larger equipment, such as grain harvesting combines, 4-wheel drive tractors, and accessories. There are numerous medium and small firms in the industry. They usually specialize in a particular line or type of equipment, such as milking, poultry, or irrigation equipment. Many of them serve local markets for highly specialized equipment. The smaller firms also make lawn and garden equipment, such as walk-behind lawnmowers and snowblowers.

Farm machinery manufacturers are concentrated in the Farm Belt, with most plants in midwestern States—Illinois, Wisconsin, Minnesota, Iowa, Nebraska, and

Kansas. Texas and California also have a large number of plants.

The largest export market for U.S. manufacturers is Canada. In turn, Canada provides the largest amount of imports of farm machinery into the United States.

Employment and hours rapidly adjusted

Over the 1958–80 period, the number and hours of production workers and nonproduction workers in the farm machinery industry have grown at similar rates. Production workers increased at an average annual rate of 1.7 percent and their hours grew 1.5 percent. Nonproduction workers grew at rate of 1.7 percent, and their hours increased at a rate of 1.8 percent.

Year-to-year changes in employment and hours in this industry tend to move in a similar but less volatile pattern than changes in output. This indicates that the industry can adjust its hours and employment fairly rapidly to changing demand. For example, when demand is falling overtime usually is cut, the number of shifts worked are reduced, the normal summer shutdowns may be extended, and workers may be laid off.

The extent of the adjustments in hours due to changes in demand is influenced by the occupational makeup of the work force. In the farm machinery industry, the largest occupational group is operatives, most of whom are assemblers. Welders, precision machine operators, punch and stamp machine operators, and transportation operators also are important. These employees, along with laborers (mainly freight handlers) are most affected by reductions in demand. The industry also employs a large group of craftworkers—machinists, mechanics, tool and die makers, and blue-collar supervisors.[3] Craftworkers are least affected by declines in production; because of their skill levels, employers are reluctant to lay them off for fear that they may not be available when demand picks up.

Technology aids productivity

Technological change varies greatly among plants in the farm machinery industry. The more advanced highly sophisticated equipment is used, for the most part, by larger firms engaged in mass production of various products. Slower changes are undertaken by the smaller firms which make short runs of highly specialized products and generally have limited capital.[4]

The level of complexity of farm machinery manufacturing differs greatly depending on the product, which can range from a simple plow pulled by a tractor to a complex self-propelled grain harvesting combine. However, there are factors common to most farm equipment manufacturing: most of the components are made of iron and steel; they are shaped by such processes as casting, cutting, stamping, punching, boring, and machining; and they are joined to form the final product in an assembly operation which uses welding and fastening with air powered tools. Farm machinery is usually finished by painting, either in the parts stage or as a completed unit.

Because of the complex nature of many of the products, the varied manufacturing operations involved in producing units, and the fact that farm machinery manufacturing is a mature industry with many old plants, there are numerous areas that are subject to technological change. The larger companies usually make most of the parts they assemble into the final product. Therefore, the technological innovations they employ cover a range of manufacturing operations and have resulted in significant labor savings.

During the 1960's, capital expenditures per employee for new plant and equipment were consistently below the average for all manufacturing industries. However, because of sustained demand for farm equipment in the early 1970's which strained the industry's capacity,[5] firms began to increase their capital expenditures for new plant and equipment. By 1975, capital expenditures per employee had almost tripled, compared to the level in 1970. This resulted in the installation of advanced manufacturing equipment and large scale plant modernization and probably was one of the factors leading to a higher rate of productivity increase during the 1970's than during the earlier decade.

Computers are among the widespread innovations with significant impact upon the industry. They are used for many functions, including inventory control, data collection, tracking progress of semi-completed products, design, and for numerous accounting and other business purposes. In recent years, computers have been more directly used for manufacturing operations on the factory floor.

Numerically controlled machine tools are used extensively by major companies in the manufacture of the parts used in assembling farm machinery. A recent innovation is computerized numerically controlled machine tools, which are more versatile than standard equipment because they can be programmed for changes by the operator rather than from tapes. One unit installed in a large firm is a completely computer-controlled gear case transfer line, using numerically controlled machine tools, where parts automatically go through 87 machining operations.[6]

One plant is experimenting with a change in machine tool layout, from the traditional setup consisting of banks of individual machines designed for a single operation to cells of machine tools based on workflow. This new layout requires high volume, but has cut bottlenecks in production and has resulted in operating efficiencies.

Automatic welding has replaced manual welding in a number of installations. In addition, industrial robots

are being introduced for welding functions, resulting in more versatile automatic welding operations.

Significant efforts have been made to increase efficiency in materials handling and warehousing functions. These functions are very important because of the numerous parts that must be moved, the many operations that must be carried out, and the large size of the factories involved in the manufacture of the more complex farm machines. A number of plants have installed computerized automatic warehousing and materials handling systems. In one plant, such a system is used for the materials receiving warehouse. The system is located in a special high rise building attached to the single story plant. Materials are shipped in using the plant's containers, logged on the computer, and moved automatically to a preassigned location. When needed, they are called for by the computer, which automatically sends a remote controlled sideloader for them, and are sent via conveyor to the location requesting them. This warehouse is run by a single computer operator. The installation of this system resulted in substantial labor savings, while doubling warehouse capacity, because the previously used equipment required numerous forklift operators.

Sideloaders are an important innovation in the industry, even though they require operators. They are narrower and higher than the conventional forklifts which they replace, allowing for increased storage space and versatility in the warehouse. Sideloaders are increasingly being used in semi-automatic computerized high rise warehousing systems installed in a number of plants.

An example of the most advanced technology for assembly line manufacture in the industry is a recently built tractor plant designed specifically for computer control.[7] This plant is unique in that almost all phases of its operations are computer controlled or directed. The plant has high rise computerized automatic warehouses. The parts to be assembled are programmed to move in the correct sequence to produce a finished tractor via conveyor through the various assembly lines. This is a major advance over the system where parts are made in advance and stored until needed, boxes of parts are moved to the assembly line via forklift trucks, and assemblers pick the correct parts out of the boxes to assemble the final product. The new plant uses industrial robots for welding and painting. The robotic painting machines are programmed to move their spray guns to paint the correct part of the tractor chassis as it moves by on the conveyor line. This differs from conventional automatic spray painting equipment, which uses fixed spray guns, in that it more closely approximates a human spray painter. Almost all welds for the frame of the tractor cabs made at this plant are done on an electronically controlled automatic framing buck which is run by a single operator. The assembly lines are set up so that fasteners and other small parts are fed directly to the assemblers at the correct height for their use. This plant's design significantly cuts parts inventory, reduces handling, increases manufacturing efficiency, and results in overall labor savings.

Besides robotic painting, which is just being introduced in the industry, there are a number of other innovations that increase painting efficiency. One system, electrostatic painting, has been used for a number of years. In this process, electrically charged parts move through an automatic paint spray booth, with the paint mist attracted to the charged part. Another innovation is electric dip paint lines, in which charged parts are dipped into a paint-filled tank from which paint is precipitated out on the part. These systems have resulted in savings in both paint and labor.

While the advanced innovations are most readily adapted by the larger multiline companies, smaller firms in the industry tend to introduce new technology more slowly. Many of the latter specialize in a particular product, such as pipeline milking units or self-propelled irrigation systems. Although these units are usually produced from common components (pipes, tanks, spray guns, and pumps), they are generally assembled to fit a particular farmer's need. Because of the semicustom nature of production used by these smaller firms, it is difficult to adapt much of the available new technology which is designed for volume production. In addition, many of the smaller firms are located in rural areas near the farms they serve and do not have the access to the capital markets as do the major companies.

Future trends uncertain

Changes in output and productivity in the farm machinery industry are expected to continue to reflect changes in farm income. In the near future, the outlook for farm income is uncertain. It has been falling since 1979; and currently, there are pressures on farm prices that are expected to slash farm profits. In addition, such factors as high interest rates and high fertilizer and pesticide costs are also expected to reduce farm income. The export market is uncertain, and farm prices are down. This situation could result in a continuation of the recent negative pressure on demand for farm machinery. In addition, technological changes in the near future may be affected by the financial difficulties of a number of the major companies in the industry, which are expected to limit capital expenditures for new plant and equipment.

Over the long term, modernization of plant and equipment is expected to continue in the farm machinery industry, with particular emphasis on labor savings and cost reduction. These changes will be fueled by possible competition with Japan in the market for larger

farm equipment, which is presently dominated by U.S. concerns. Japan currently holds a large share of the U.S. market for small tractors.[8] The future will see growing installation of automatic welding equipment and increasing use of industrial robots for welding, painting, and other high volume, difficult operations. Computers will increasingly be used for manufacturing operations and in design functions. □

FOOTNOTES

[1] Average annual rates of change are based on the linear least squares trends of the logarithms of the index numbers. The farm machinery and equipment industry is designated industry 352 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 farm machinery and equipment, and garden tractors and lawn and garden equipment. A technical note describing the indexes is available from the Office of Productivity and Technology, Bureau of Labor Statistics, Washington, D.C. 20212. The indexes for this industry will be updated and included in the Bureau of Labor Statistics' annual bulletin, *Productivity Measures for Selected Industries.*

[2] *Statistical Abstract of the United States, 1980* (U.S. Department of Commerce, 1980), p. 686.

[3] *1970 Census of Population, Occupation by Industry,* Vol. PC(2)-7C (U.S. Department of Commerce, 1972), pp. 281–88.

[4] Based on discussions with industry experts.

[5] *U.S. Industrial Outlook, 1974* (U.S. Department of Commerce, 1973), p. 301.

[6] *John Deere Harvester Works* (Deere and Company, 1979), p. 10.

[7] *John Deere Tractor Works* (Deere and Company, 1980), pp. 6–18.

[8] *U.S. Industrial Outlook, 1981* (U.S. Department of Commerce, 1980), p. 260.

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 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 were 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 close to the preferred output measure.

Employment and employee hour indexes were derived from data from 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.