Productivity trends in agricultural chemicals

Output per hour in the manufacture of synthetic fertilizers and pesticides increased almost as much as that for all manufacturing; the gain is tied partially to technological innovation

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Output per hour of labor in the manufacture of synthetic fertilizers and pesticides rose at an average annual rate of 2.2 percent between 1972 and 1986.[1] This rise reflected an increase of 1.3 percent a year in output and a decline of 0.9 percent a year in employee hours. The improvement in productivity compares with an average annual increase of 2.5 percent for manufacturing as a whole. As the following tabulation shows, productivity rates for the four individual agrochemical industries varied widely from the average for the group, with establishments producing nitrogenous fertilizer recording output-per-hour advances of close to 4 percent a year and establishments specializing in the mixing of fertilizers registering no strong trend at all. The pesticide industry stood in between, with a rate nearly equal to that for all manufacturing.

Industry	Average annual rate (percent), 1972–86: Productivity	Output	Employee hours
Agricultural chemicals	2.2	1.3	−0.9
Nitrogenous fertilizer	3.9	1.8	−2.0
Phosphatic fertilizer	2.0	.6	−1.4
Fertilizer mixing	.4	−1.8	−2.2
Pesticides	2.3	3.6	1.3

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The long-term productivity trend slowed somewhat over the second half of the study period, from 3.9 percent annually for the industry group as a whole during 1972–79 to 2.5 percent a year during 1979–86. (See table 1.) Nitrogenous and phosphatic fertilizers did not partake in the slowdown, which was dominated by a deceleration in productivity in the pesticide industry. In contrast to the first half of the period, when growth in output was accompanied by (somewhat lower) gains in employee hours in all agricultural chemicals industries, both output and employee hours declined during the second half. With the latter declining more steeply than the former, productivity improved.

Year-to-year movements fluctuated widely, with productivity rising as much as 13 percent in 1984 and dropping as much as 15 percent in 1973. These movements were tied to swings in demand and, in turn, output, and were accompanied by somewhat smaller swings in hours.

Sources of improvements in productivity in the nitrogenous and phosphatic fertilizer industries include technological advances, economies of scale, and during the 1980's, the elimination of smaller, less efficient plants.[2] Strength in the productivity of pesticide manufacturing was linked to surging demand during the seventies and declining employment in the eighties. But on balance, *levels* of employment in the eighties ran above those in the seventies, owing to increases in the industry's marketing and research and development (R&D) personnel that were necessitated in part by more stringent environmental and registration regulations.[3]

Tables 2 through 6 present a year-by-year breakdown of output per employee hour, output, and employee hours for the agrochemical industry group as a whole and for each of its four component industries from 1972 to 1986.

Production and role of agricultural chemicals

Nitrogenous fertilizer represents one of three primary plant food nutrients, the other two being phosphates and potash (a product of the mining industry not included in the productivity and related measures discussed here).[4] Nitrogenous fertilizer materials are produced by the synthesis of natural gas to form anhydrous (waterless) ammonia, an important nitrogenous fertilizer itself. In 1985, about one-half of all the anhydrous ammonia produced in the United States was absorbed by nitrogenous fertilizer materials. One-third of this was directly applied to the soil by users, while the remaining two-thirds entered into the production of ammonium nitrate and urea.[5] Production of urea, which has the highest nitrogen content of any solid nitrogenous fertilizer material, has steadily gained in importance, attaining par with nitrate production in 1978 in terms of tonnage. In general, nitrogen solutions have expanded their share of total nitrogenous materials since the early eighties from 28–33 percent to 36 percent, but the high capital outlay required to apply them to the soil tends to retard their further expansion.[6]

Phosphatic fertilizer is derived by the action of sulfuric acid on pulverized phosphate rock, resulting in superphosphate. It is the oldest synthetic fertilizer in use, but by the mid-1970's it was virtually displaced by diammonium phosphate. Diammonium phosphate, which consists of phosphoric acid treated with ammonia, is a multinutrient fertilizer material. While the production of conventional superphosphate declined by half between 1974 and 1984, that of diammonium phosphate nearly tripled. A high proportion of active nutrients, high water solubility, ease in application, and a favorable price have given this material a decided advantage over the other.[7]

Table 1. Productivity in agricultural chemicals, 1972–79 versus 1979–86

Industry	Average annual rates, percent					
	Output per hour		Output		Employee hours	
	1972–79	1979–86	1972–79	1979–86	1972–79	1979–86
Agricultural chemicals	3.9	2.5	5.8	-2 4	1.9	-4.7
Nitrogenous fertilizer	3.5	3.7	7.1	-3.3	3.5	-6.7
Phosphatic fertilizer	3.0	3.7	3.5	-1 6	.5	-5.1
Fertilizer mixing	4.0	.6	3.4	-6 1	-.6	-6.
Pesticides, including agricultural chemicals n.e.c.[1]	4.5	1.4	9.0	- 4	4.3	-1.8

[1]Pesticides account for close to nine-tenths of this industry component.
n.e.c. = not elsewhere classified.

In combination with pesticides (especially herbicides), synthetic fertilizer has contributed decisively to rising yields per acre. Representing about 9 percent of the value of final demand for food grains, feed grains, cotton, and such oil-bearing legumes as soybeans, fertilizer and pesticides have helped raise yields per acre as much as 24 percent from 1972 to 1985, as the following tabulation shows:[8]

Crop	*Yields per acre*		*Percent increase*
	1972	*1985*	
Wheat (bu.)	32.7	37.5	14.7
Corn (bu.)	97.0	118.0	21.6
Cotton (pds.)	50.7	63.0	24.3
Soybeans (bu.)	27.8	34.1	22.7
Hay (tons)	2.2	2.5	13.6

Output trends

Output of agricultural chemicals rose at an average annual rate of 1.3 percent between 1972 and 1986. The trend showed a sharp break beginning in 1979. Until then, output of the industry group climbed 5.8 percent a year; thereafter, it dropped 2.4 percent annually. The following tabulation gives the breakdown by industry:

Industry	*Average annual output rates, in percent*		
	1972–86	*1972–79*	*1979–86*
Agricultural chemicals	1.3	5.8	-2.4
Nitrogenous fertilizer	1.8	7.1	-3.3
Phosphatic fertilizer	.6	3.5	-1.6
Fertilizer mixing	-1.8	3.4	-6.1
Pesticides	3.6	9.0	-0.4

The rise in the output of agricultural chemicals during the seventies, as well as its subsequent decline, was closely related to parallel trends in the production of grains, cotton, soybeans, and other crops. Production of these crops rose at an average annual rate of 3.2 percent during that decade, and then declined by 0.5 percent a year into the mid-eighties. Per-acre use of nitrogenous fertilizer materials grew for feed grains (mainly corn) and food grains (chiefly wheat) over the entire study period, but tended to shrink for phosphates.[9] However, the pattern of per-acre application of fertilizer did not much influence total fertilizer use. Rather, it was the contraction in acreage planted with the major crops that underlay the 1979–85 decline in output, as shown in the following tabulation, adapted from the U.S. Department of Agriculture's publication, *Agricultural Statistics, 1986:*

Crop	*Percent change in acreage planted*	
	1972–79	*1979–85*
Wheat	30	6
Corn	21	2
Cotton	0	-24
Soybeans	52	-12

The reduction in acreage planted, which resulted from changes in official farm programs compelled by declining exports and accumulating stocks, also led to cutbacks in the application of pesticides in agriculture (which accounts for roughly three-quarters of their total use).[10] Between 1972 and 1979, total output of pesticides rose strongly, even as insecticide applications to the major crops were reduced. New, wide-spectrum herbicides, mostly of the preemergent variety, were introduced and quickly became important. Postemergent herbicides then gained favor in the early eighties. These are applied when the weed species has been determined by the farmer. They were considered more effective than the preemergent herbicides in specific applications. However, preemergent herbicides have made a comeback in recent years. The expanding use of herbicides was spurred on in agriculture by the rapid growth in conservation tillage as a moisture- and soil-conserving production practice (such use reduces the need for cultivation) and, to an extent, by the rising cost of fuel during the seventies.[11]

Employment and occupational pattern

Employment in agricultural chemicals, numbering 57,000 in 1986, declined at an average annual rate of nearly 1 percent—or by a total of 15 percent—between 1972 and 1986. Hours declined at nearly the same rate, rising 11 percent over the first 7 years of the period, but plummeting 24 percent over the last 7. Thus, the trend in hours exhibited the same break noted for the trends in productivity and output, although it was more pronounced. Following is the industry breakdown:

Industry	*Average annual percent change, employee hours*	
	1972–79	*1979–86*
Agricultural chemicals	1.9	−4.7
Nitrogenous fertilizer	3.5	−6.7
Phosphatic fertilizer	.5	−5.1
Fertilizer mixing	−.6	−6.6
Pesticides	4.3	−1.8

The decline in the number of production workers was more than twice as high (16 percent) as that for nonproduction workers (7 percent) during the study period. (No significant change in employment was experienced by all manufacturing.) The proportion of nonproduction workers, 37 percent of the group's total employment in 1972, increased slightly to 39 percent; in manufacturing as a whole, the ratio rose from 27 to 33 percent. Hourly wages ran 17 percent above the manufacturing average in 1986, as against 1 percent in 1972. The rise in the ratio was evidently not occasioned by significant changes in skill mix.[12] Rather, the more senior and experienced workers retained their jobs in the face of reductions in the work force, and that made for an upward wage drift.[13]

Table 2. Output per employee hour and related indexes in the agricultural chemicals industry group, 1972–86[1]
[1977=100]

Year	Output per employee hour			Output	Employee hours		
	All employees	Production workers	Nonproduction workers		All employees	Production workers	Nonproduction workers
1972	75.3	76.5	72.9	67.0	89.0	87.6	91.9
1973	86.7	87.4	85.2	76.3	88.0	87.3	89.6
1974	95.9	95.4	97.1	89.2	93.0	93.5	91.9
1975	86.7	87.8	84.6	84.3	97.2	96.0	99.7
1976	92.4	94.4	88.3	90.2	97.6	95.6	102.1
1977	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1978	101.4	108.1	97.9	100.0	98.6	97.0	102.1
1979	102.0	101.4	103.2	102.0	100.0	100.6	98.8
1980	97.2	97.7	95.9	103.4	106.4	105.8	107.8
1981	97.7	98.1	96.8	104.1	106.5	106.1	107.5
1982	94.5	99.9	84.4	88.5	93.7	88.6	104.8
1983	106.2	111.8	95.8	88.9	83.7	79.5	92.8
1984	119.8	124.3	111.3	100.3	83.7	80.7	90.1
1985	115.6	121.2	105.0	94.9	82.1	78.3	90.4
1986	108.8	115.2	97.2	82.7	76.0	71.8	85.1
	Average annual percent change						
1972–86	2.2	2.6	1.5	1.3	−0.9	−1.3	−0.2
1981–86	3.7	4.3	2.4	−2.3	−5.8	−6.4	−4.6

[1]Includes producers of nitrogenous fertilizer, manufacturers of phosphatic fertilizer, establishments engaged in fertilizer mixing, and manufacturers of agricultural chemicals not elsewhere classified (mostly pesticides).

Overtime worked in the agrochemical industry by far exceeded the manufacturing average in most years of the study period. In 12 of the 15 years examined, overtime ran ahead by one-third again as much or more, in 6 by one-half again as much. Like many other chemicals, agricultural chemicals are manufactured by means of continuous processes, operated around the clock and worked by employees on either overtime or additional shifts. According to industry sources, consistently high overtime in the industry is linked to a large extent to the highly seasonal pattern of industry output, combined with the difficulty in hiring and training additional workers on a seasonal basis. Industry sources also state that fertilizer manufacturers prefer to hold on to experienced workers to oversee and maintain instruments and equipment that are highly sensitive to small changes in variables such as temperature and pressure, and to provide the ceaseless attention that is required to forestall breakdowns and costly downtime. Stability of employment in the industry is indicated by labor turnover rates. Accessions per 100 workers employed ran well below the manufacturing average in 7 of the 10 years for which data are available (1972–81), and separations in 8 of the 10.

The occupational composition of the industry differs from the manufacturing average in important respects. The industry employed a considerably higher proportion of physical and chemical scientists and technicians in 1986 (11 percent) than did manufacturing as a whole (4 percent). Blue-collar supervisors played a relatively larger role in the industry group (9 percent of employment) than in manufacturing (4 percent), as did mechanics, installers, and preparers (10 percent versus 4 percent). Occupations involving plant and systems operations also represented a much higher share of industry employment (8 percent versus 1 percent). Occupations requiring fewer skills and less training, such as machine setters and tenders, transportation and materials moving personnel, and helpers and laborers, made up a somewhat lower proportion of industry employment (31 percent) than in manufacturing (34 percent).[14]

Capacity changes and capital spending

Productive capacity in the fertilizer industries expanded by 35 percent between 1973 and 1981, but then contracted by 8 percent over the next 5 years.[15] These movements were linked with significant changes in employment, namely, a parallel rise and drop, and also affected output per hour. The following tabulation indicates the magnitudes involved:

	Percent change	
	1973–81	*1981–86*
Capacity	35	−8
Employment	18	−24
Productivity	10	9

In addition to, and notwithstanding, cutbacks in productive capacity, there occurred a decline in capacity utilization, from an average of 85 percent during the seventies to 78 percent during the early eighties for nitrogenous fertilizer, and from 80 percent to 74 percent for phosphatic fertilizer.[16]

The larger, more efficient fertilizer-producing plants survived the capacity cutbacks of the early eighties, thereby contributing to a strong improvement in productivity (as well as the large reduction in employment). Thus, the number of ammonium-producing plants with less than 1,000 tons per-day capacity dropped from 55 in 1982 to 30 in 1986, while the number of larger plants rose from 30 to 31.[17] The larger plants operate with substantially lower unit labor requirements than the smaller ones. For example, sulfuric acid produced in plants with one million tons of capacity or more required, on average, three-tenths of one employee hour per ton in each of operating and maintenance labor in 1986, half as much as that required by smaller plants. Similarly, ammonia-producing plants with a daily capacity of more than 1,000 tons reported employee-hour requirements of 8 minutes per ton for operating labor and just under 5 minutes for maintenance labor. By contrast, plants with 600–1,000 tons of daily capacity required 10 minutes and 7 minutes per ton of output. The pattern for the production of other fertilizer materials is similar.[18]

Fixed assets per worker in agricultural chemicals have been running about five times higher than the manufacturing average. The ratio rose over the study period as employment was slashed, owing largely to capacity cutbacks. Thus, of the 90 ammonia plants reported to be operating in 1980, 54 were left in early 1987, idling an estimated 5.5 million tons in productive capacity. Of 25 plants manufacturing phosphates in 1980, 13 closed, but 16 new ones were added, so that in this industry no net loss in productive capacity occurred.[19] In pesticide manufacturing, small increases in productive capacity have taken place over the past decade, but the utilization rate has shrunk, and employment losses in the industry since 1981 are partially attributable to this factor.[20]

Capital spending by establishments manufacturing agricultural chemicals declined at an average annual rate of 4.1 percent between 1972 and 1985, after adjusting for price changes.[21] The trend obscures great year-to-year volatility in such spending, however. Thus, in 1974, the industry's capital spending nearly doubled from the previous year's level, while in 1983, it dropped by close to half. Up to 1979, the annual rate rose nearly 13 percent, on average. Thereafter, it plunged by about same rate. The following tabulation is illustrative:

	Average annual percent change, capital spending	
	Agricultural chemicals	*All manufacturing*
1972–85	−4.1	2.3
1972–79	12.8	5.0
1979–85	−12.6	−1.0

The gross book value of fixed assets per worker in the industry ran close to four times that for all manufacturing in 1972 and rose to five times that average in 1982. The reason for the disparity was partly because employment in the industry dropped 10 percent, as against 1 percent in manufacturing generally, and partly because the indus-

Table 3. Output per employee hour and related indexes in the nitrogenous fertilizer industry, 1972–86
[1977=100]

Year	Output per employee hour: All employees	Production workers	Nonproduction workers	Output	Employee hours: All employees	Production workers	Nonproduction workers
1972	82.6	83.2	81.4	64.2	77.7	77.2	78.9
1973	92.6	88.7	102.7	71.6	77.3	80.7	69.7
1974	99.5	95.0	111.5	82.2	82.6	86.5	73.7
1975	94.8	93.7	97.4	83.3	87.9	88.9	85.5
1976	95.5	94.6	97.6	92.4	96.8	97.7	94.7
1977	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1978	109.5	115.4	98.3	107.3	98.0	93.0	109.2
1979	110.4	113.7	103.7	99.7	90.3	87.7	96.1
1980	124.2	125.1	122.5	111.2	89.5	88.9	90.8
1981	121.4	123.3	117.3	109.6	90.3	88.9	93.4
1982	114.7	122.9	99.6	97.0	84.6	78.9	97.4
1983	128.1	141.9	104.9	88.7	70.0	63.2	85.5
1984	152.6	164.2	131.6	103.8	68.0	63.2	78.9
1985	149.7	160.2	130.5	103.0	68.8	64.3	78.9
1986	133.5	141.7	118.1	72.0	54.7	51.5	61.8
	Average annual percent change						
1972–86	3.9	4.7	2.1	1.8	−2.0	−2.8	−0.3
1981–86	4.2	4.8	3.1	−4.8	−8.6	−9.1	−7.6

try's fixed assets grew at a somewhat faster rate than those of all manufacturing establishments until 1981.

The agricultural chemicals industry is dominated by large firms, and the growth in real capital expenditures and fixed assets from 1972 to 1981 was accompanied by an increase in the concentration of these firms. The 20 largest firms manufacturing nitrogenous fertilizer accounted for 87 percent of the value of shipments in 1982, compared with 84 percent in 1972, and the 20 largest firms producing phosphate fertilizer accounted for 92 percent, as against 83 percent in the earlier year. For pesticides, the pertinent figures were 85 percent in 1982 and 76 percent 10 years earlier. The higher concentration reflects some consolidation brought on by the extended economic downturn of the early eighties.[22]

Technological advances

Important technological breakthroughs in the production of fertilizer occurred chiefly prior to the review period. Among them was the introduction of centrifugal compressors in the manufacture of nitrogenous fertilizer. The centrifugal compressor gradually displaced the reciprocal compressor, except in smaller plants where the scale of operations made it uneconomical. Compressors are needed in the amalgamation of hydrogen and nitrogen for producing ammonia. The centrifugal compressor permits—indeed requires—lower pressures (hence, less energy per unit of output), less floor space, and less extensive piping, thus reducing maintenance labor. At the time of its inception, this new ammonia-producing technology gave rise to a program of vast nitrogenous fertilizer plant expansion. Whereas up to the early sixties, the 400-tons-a-day plant had been the rule, plants began to be built three and more times as large. The technology reduced (1) the heat requirements associated with the removal of carbon dioxide from the natural gas from which ammonia is ultimately derived in the United States, (2) the power needed in compression per ton of output, and (3) the labor per ton of output, as economies of scale afforded by the larger plants increased.[23]

Table 4. Output per employee hour and related indexes in the phosphate fertilizer industry, 1972–86
[1977=100]

Year	Output per employee hour			Output	Employee hours		
	All employees	Production workers	Nonproduction workers		All employees	Production workers	Nonproduction workers
1972	73.0	70.9	79.6	75.5	103.4	106.5	94.9
1973	88.6	85.2	99.5	81.7	92.2	95.9	82.1
1974	98.0	92.8	115.9	102.6	104.7	110.6	88.5
1975	81.8	79.4	89.2	90.4	110.5	113.8	101.3
1976	93.2	92.0	96.7	95.4	102.4	103.7	98.7
1977	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1978	97.2	96.7	98.9	98.9	101.7	102.3	100.0
1979	94.4	93.5	97.4	99.9	105.8	106.9	102.6
1980	92.9	91.3	97.7	105.2	113.2	115.2	107.7
1981	84.4	84.3	84.9	94.7	112.2	112.4	111.5
1982	88.0	91.9	78.6	84.7	96.3	92.2	107.7
1983	108.1	108.3	107.2	94.9	87.8	87.6	88.5
1984	121.8	124.9	114.0	108.2	88.8	86.6	94.9
1985	113.5	119.8	99.3	99.3	87.5	82.9	100.0
1986	104.7	114.2	84.9	79.5	75.9	69.6	93.6
	Average annual percent change						
1972–86	2.0	2.8	0.0	0.6	-1.4	-2.2	0.5
1981–86	5.8	7.3	2.2	-.8	-6.2	-7.5	-2.9

Table 5. Output per employee hour and related indexes in the fertilizer mixing industry, 1972–86[1]
[1977=100]

Year	Output per employee hour			Output	Employee hours		
	All employees	Production workers	Nonproduction workers		All employees	Production workers	Nonproduction workers
1972	79.7	82.3	74.9	73.0	91.6	88.7	97.4
1973	84.2	85.9	81.0	82.1	97.5	95.6	101.3
1974	95.6	97.8	91.3	84.3	88.2	86.2	92.3
1975	96.2	100.1	89.0	84.5	87.8	84.4	94.9
1976	104.3	106.5	100.0	87.2	83.6	81.9	87.2
1977	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1978	102.6	104.8	98.6	89.7	87.4	85.6	91.0
1979	107.0	100.6	122.8	94.4	88.2	93.8	76.9
1980	90.6	92.2	87.4	99.7	110.1	108.1	114.1
1981	83.3	84.5	80.9	87.1	104.6	103.1	107.7
1982	79.8	84.1	72.4	64.1	80.3	76.2	88.5
1983	91.9	96.1	84.7	68.4	74.4	71.2	80.8
1984	99.1	100.6	96.3	67.9	68.5	67.5	70.5
1985	102.6	105.7	96.6	68.1	66.4	64.4	70.5
1986	95.7	98.9	89.6	64.3	67.2	65.0	71.8
	Average annual percent change						
1972–86	0.4	0.5	0.3	-1.8	-2.2	-2.2	-2.1
1981–86	4.4	4.4	4.4	-3.8	-7.9	-7.9	-7.8

[1] Includes establishments which mix, but do not manufacture, fertilizer

Two major technological breakthroughs in the sixties provided the basis for shaping today's phosphate industry. These developments also led to changes in the overall industry system of production, distribution, and even use at the farm level. The first breakthrough was the process for producing granular diammonium phosphate from wet process acid. This technology made it possible to concentrate U.S. phosphate production in Florida and to take advantage of the economics of mining, large-scale chemical plants, and water transportation of high-analysis fertilizers to serve domestic and growing export markets. The other technological innovation led to the production of ammonium polyphosphate solutions from wet process acids. This technology paved the way for subsequent growth and development of the fluid fertilizer industry.

The diffusion of these developments was gradual, carrying well into the review period, and in fact, the methods devised remain the technology of choice today. It was a major factor underlying the productivity improvements during the period.[24]

The rising importance of ammoniated or diammonium phosphates led to changes in the production processes of fertilizer that occurred chiefly during the early seventies. The shift to ammoniated phosphates encouraged the innovation of the so-called pipe cross reactor in 1975 and its subsequent diffusion throughout the industry. This device raised the efficiency of amalgamating ammonium and phosphate and displaced the tank reactor, which was more energy intensive. The pipe cross reactor does not require either pumping or pipelines for moving its contents, which it spills directly into a granulator for granulation and cooling. The worker who operates the granulator can at the same time operate the pipe reactor, which use of the tank reactor did not permit. Hence, direct labor per unit of output was reduced, as was the labor needed to maintain pipes and pumps.

In addition to heightening the accuracy of a given product mix, advances in instrumentation are likely to have eased maintenance tasks and lowered unit labor requirements. Solid-state instruments have gradually replaced tubing—for example, in measuring mass flow—so that the weight and volume of a material entering a process could be determined in combination, rather than separately. Such measuring devices have come to be linked to feedback systems which ensure an accurate mix at all times. Process operators are enabled to perform more than one task, especially in the blending of fertilizer materials.[26]

Research and development

Products manufactured by the agricultural chemicals industry are regarded as technology intensive by the National Science Board, which defines research intensity as R&D expenditures in excess of 2.6 percent of value added.[27] In terms of dollars spent, R&D in agricultural chemicals is conducted predominantly by the pesticides industry, for which pertinent expenditures have accounted for between 13 and 20 percent of value added. The bulk of pesticides research has gone into the development of new products and the refinement of existing products. Only between 10 and 14 percent of total R&D expenditures have been devoted to process research, which would be the most likely research to affect unit labor requirements directly.[28] Specific information on such effects is not available. Not unlike pharmaceuticals, pesticides are manufactured mostly by multistep batch processes, which typically do not yield significant scale economies. Although these processes have in many cases been automated, the demand for individual products, of which more than 170 have been listed for the 1970's, is relatively small. Some authors believe that "productivity improvements cannot be large in the industry."[29]

Research and development in fertilizers has been conducted mostly by the National Fertilizer Development Center of the Tennessee Valley Authority.[30] In the fertilizer industry, product innovation is more closely linked with process innovation than in pesticides, and it also tends to reduce unit labor requirements more demonstrably. For example, the TVA center developed diammonium phosphate, the production of which involved a process that doubled output from a plant of a given size in comparison with output of an earlier, industry-innovated ammonium phosphate fertilizer.[31] Research and development efforts in agricultural chemicals are not focused primarily on labor savings. Rather, they are aimed mainly at reducing fertilizer costs to farmers, which entails a search for ways to reduce energy inputs, storage, handling, and transportation costs, and ease in application.[32] Nonetheless, all new technologies have reduced unit labor requirements in fertilizer production.[33]

Table 6. Output per employee hour and related indexes in the agricultural chemicals n.e.c. industry, 1972–86[1]
[1977=100]

Year	Output per employee hour: All employees	Output per employee hour: Production workers	Output per employee hour: Nonproduction workers	Output	Employee hours: All employees	Employee hours: Production workers	Employee hours: Nonproduction workers
1972	69.5	76.9	59.4	56.7	81.6	73.7	95.1
1973	83.0	92.6	70.4	70.4	84.8	76.0	100.0
1974	90.9	99.3	79.2	85.4	94.0	86.0	107.8
1975	79.8	86.5	70.3	79.2	99.3	91.6	112.6
1976	81.7	89.5	70.8	86.0	105.3	96.1	121.4
1977	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1978	98.6	99.3	97.2	103.8	105.3	104.5	106.8
1979	99.7	100.8	97.8	112.1	112.4	111.2	114.6
1980	88.6	90.7	85.1	98.3	111.0	108.4	115.5
1981	105.7	104.8	107.2	122.9	116.3	117.3	114.6
1982	95.7	101.1	87.7	105.6	110.3	104.5	120.4
1983	97.2	104.1	87.2	96.5	99.3	92.7	110.7
1984	110.0	112.0	106.8	115.1	104.6	102.8	107.8
1985	103.1	106.5	97.7	105.3	102.1	98.9	107.8
1986	103.1	105.1	99.9	105.7	102.5	100.6	105.8
	Average annual percent change						
1972–86	2.3	1.7	3.1	3.6	1.3	1.9	0.5
1981–86	.6	.7	.5	-1.7	-2.3	-2.3	-2.1

[1]Pesticides represent nearly nine-tenths of this industry component. Pesticides denote herbicides, insecticides, and fungicides

Outlook

Minor gains in output per hour appear likely for the agricultural chemicals industries over the next few years. To some extent, these gains will arise from further reductions of less efficient plants, especially in fertilizer manufacturing. A tally of announcements by fertilizer-producing companies indicates minor cutbacks in capacity for the production of ammonia and ammonium phosphate.[34] Other industry sources believe that a slow growth in consumption is resuming, albeit not at the peak levels of 1981.[35] Some authorities believe that as the year 2000 approaches, up to 200 world-scale plants featuring updated production technologies will have to be built.[36] Again, the design of these technologies is likely to emphasize energy and material savings, but lower maintenance costs and lowered risks of downtime would normally also be an objective. If the aims are achieved, unit labor requirements would be reduced as well.

Bureau of Labor Statistics medium-level projections of the agrochemical industry's employment needs over the next 12 years indicate a 23-percent decline in employment from 1986 levels. Even the high projection shows a 14-percent decline. However, some industry analysts doubt that employment will fall as much as projected. □

[1]Agricultural chemicals are classified as No. 287 in the *Standard Industrial Classification Manual* published by the Office of Management and Budget. The group of producers consists of establishments manufacturing nitrogenous fertilizer (SIC 2873), those producing phosphatic fertilizer (SIC 2874), those engaged in fertilizer mixing (SIC 2875), and those manufacturing pesticides and agricultural chemicals not elsewhere classified (n.e.c.; SIC 2879). Productivity and related measures have been computed by BLS for all four of the group's industry components, as well as for the three-digit group itself.

Average annual rates of change presented here are based on linear least squares of the logarithms of the index numbers. All the measures will be updated annually and will appear in the annual BLS bulletin, *Productivity Measures for Selected Industries*.

[2]Labor costs in agricultural chemicals, as in other basic chemical processing industries, account for only a small proportion of total costs. In ammonia production, for example, costs of energy and materials averaged 83 percent per ton in 1982, as against 4 percent for maintenance and operating labor. The comparable figures for phosphates were 91 percent and 3 percent per ton. Hence, technological improvements in the fertilizer industries have centered on material and energy savings rather than on labor savings. (*The Fertilizer Institute, Ammonia Production Cost Survey*, year ended December 31, 1986, and *The Fertilizer Institute, Phosphate Fertilizer Production Cost Survey*, year ended December 31, 1986; compiled by National Fertilizer Development Center, Economics and Marketing Staff, Muscle Shoals, AL. The surveys include earlier years.)

[3]Industry sources.

[4]There are also many secondary soil nutrients, such as calcium, magnesium, and sulfur, as well as micronutrients. See *The Fertilizer Handbook* (Washington, DC, The Fertilizer Institute, 1982) for a discussion of subjects related to fertilizer production and use.

[5]*The Fertilizer Handbook*, p. 59; see also J. Darwin Bridges, *Fertilizer Trends*, Muscle Shoals, AL, National Fertilizer Development Center, TVA, Bulletin Y-195, October 1986, pp. 12, 13.

[6]Industry sources.

[7]*The Fertilizer Handbook*, p. 62.

[8]U.S. Department of Commerce, *The Detailed Input-Output Structure of the U.S. Economy*, Vol. 1 (Washington, DC, U.S. Government Printing Office, 1977), and *Agricultural Statistics, 1986*, various tables. "It is estimated that fertilizer use substitutes for more than 150 million acres of land plus labor, fuel and equipment requirements." [*The Impact of TVA's National Fertilizer Program* (Muscle Shoals, AL: National Fertilizer Development Center, 1983), p. 5.]

[9]U.S. Department of Agriculture, Economic Research Service, *Agricultural Resources: Inputs, Situation and Outlook Report*, January 1987, Table 7.

[10]*Agricultural Statistics, 1986*.

[11]Howard J. Sanders, "Herbicides," *Chemical and Engineering News*, August 3, 1981, p. 20ff. Also, industry sources, as well as information from the National Fertilizer Development Center.

[12]Information from the Chemical Workers Union's research office.

[13]Industry sources. *The National Survey of Professional, Administrative, Technical, and Clerical Pay, March 1985* (BLS Bulletin 2208) states that changes in average salaries reflect a variety of factors: "For example, an expansion in force may increase the proportion of employees at the minimum salary of a rate range for a work level, which would tend to lower the average for a job; a reduction or a low turnover in the work force may have the opposite effect." (p. 40).

[14]BLS matrices on employment by industry and occupation.

[15]*North American Fertilizer Capacity Data*, July 1987 (Muscle Shoals, AL, National Fertilizer Development Center, Economics and Marketing Staff).

[16]U.S. Bureau of the Census, *Survey of Plant Capacity*, Current Industrial Reports, various years.

[17]*The Fertilizer Institute Ammonia Production Cost Survey*, year ended December 31, 1986.

[18]*Ibid.*

[19]*Ibid.*

[20]*Inputs: Outlook and Situation*, October 1983, and *Agricultural Resources*, January 1987 (U.S. Department of Agriculture, Economic Research Service).

[21]Capital spending data are taken from Table B-3, *Economic Report of the President, January 1987*, and were deflated by the implicit price deflators for fixed nonresidential investment.

[22]Industry information.

[23]G. Russell James, "Large Ammonia Synthesis Plants: Their Effect on Production Costs," in *The Impact of New Technology*, Fertilizer Production and Marketing Conference, TVA, Knoxville, TN, October 4–6, 1967, p. 27. See also pertinent chapters in A.V. Slack, *Fertilizer Development and Trends, 1968* (Park Ridge, NJ, Noyes Development Corp., 1968).

[24]*The Impact of TVA's National Fertilizer Program*, p. 7.

[25]National Fertilizer Development Center, *Transferring Technology from TVA's National Fertilizer Development Center*, Muscle Shoals, AL, 1982, p. 21.

[26]Information from the National Fertilizer Development Center.

[27]*Science Indicators*, 1985 report, p. 197.

[28]National Agricultural Chemicals Association, *Industry Profile Survey*, published annually, various years.

[29]Basil Achilladelis and others, "A Study of Innovation in the Pesticide Industry: Analysis of the Innovation Record of an Industrial Sector." *Research Policy*, no. 16, 1987, p. 176.

[30]"Technology from the [TVA research center] is estimated to be involved in 3 of every 4 tons of fertilizer produced in the United States." *Transferring Technology from TVA's National Fertilizer Development Center*, p. 5.

[31]*The Impact of TVA's National Fertilizer Program*, p. 10.

[32]An example of a result of this effort is the rise in the proportion of nutrient per ton of fertilizer delivered to the user. In the late 1940's, each ton of fertilizer moved 400 pounds of nutrient; in 1985, it moved 900 pounds. "As a least common denominator, the concept of higher analysis fertilizers is the major source of benefits of fertilizer R&D." T.H. Foster, *NFDC: A National Investment Paying Global Dividends*, Muscle Shoals, AL, TVA Office of Agricultural and Chemical Development, June 1985, p. 3.

[33]*The Impact of New Technology*, p. 7; information from the National Fertilizer Development Center.

[34]*North American Fertilizer Capacity Data*.

[35]*Ibid.*

[36]"Future Fertilizer Plants: What Will They Be Like?" *Chemical Engineering*, April 1, 1985, p. 21 ff. That as many as 200 world-scale plants will be needed by the year 2000 has been questioned by industry sources.

APPENDIX: Measurement techniques and limitations

The indexes of productivity measure changes in the relation between the output of an industry and the employee hours expended on that output. An index of productivity (for example, output per employee hour) is derived by dividing an index of output by an index of industry employee hours.

In the absence of adequate physical volume data for three of the four industries making up the agricultural chemicals group, real output was calculated in terms of the deflated value of shipments, adjusted for inventory change, for each product group. Changes in prices were removed from current-dollar values by means of appropriate price indexes at various levels of subaggregation for a variety of products in each group. For the industry classified as agricultural chemicals not elsewhere classified (including mostly pesticides), the output measure for 1972–81 has been derived from physical quantity data furnished by the National Agricultural Chemicals Association. From 1982 forward, the measure is based on deflated value data. All output segments were combined to a total output index, by employee-hour weights.

Complete output data are available only for years when a Census of Manufactures is taken (such as 1972, 1977, and 1982). For the intercensal years, the data are based on samples. Therefore, these data are benchmarked to Census-year data.

The productivity indexes relate total output to one input—labor. The indexes do not measure the specific contribution of labor, capital, or any other single factor. Rather, they reflect the joint effects of such factors as changes in technology, capital investment, capacity utilization, plant design and layout, skill and efforts of the work forces, and managerial ability.

A note on communications

The *Monthly Labor Review* welcomes communications that supplement, challenge, or expand on research published in its pages. To be considered for publication, communications should be factual and analytical, not polemical in tone. Communications should be addressed to the Editor-in-Chief, *Monthly Labor Review*, Bureau of Labor Statistics, U.S. Department of Labor, Washington, DC 20212.
