# Productivity trends in the photographic equipment and supplies industry

*The introduction of computers and automated equipment, along with modifications in corporate strategy, inventory control, and employee training, was a significant factor in productivity growth during the 1980's*

Stuart Kipnis
and
Clyde Huffstutler

Prior to World War II, the photographic equipment and supplies industry primarily manufactured cameras, film, and projectors. In the postwar years and especially since the late 1950's, the industry has helped to develop and refine several products that have had a substantial impact on our lives. Photocopiers, which have become the largest item produced in the industry during the last 20 years, have greatly boosted office productivity. Advances in x-ray technology have led to significant improvements in health care. Micrographics, "instant" photography, and audiovisual communications are other examples of important product developments.

By responding to user demands for new and innovative products, the industry experienced strong growth throughout the 1960's and 1970's. However, as in the case of other advanced electronic industries, intense competition from foreign manufacturers dampened output growth during the 1980's. To regain a competitive edge, a number of the major U.S. manufacturers of photographic products have recently implemented broad, corporate-wide restructuring plans.

This study introduces a new Bureau of Labor Statistics measure of productivity in this industry. It seeks to capture the dynamics of an industry that has gone from a period of strong output growth to one of slower growth and is currently attempting to recover.

Output per employee hour in the photographic equipment and supplies industry increased at an average annual rate of 4.3 percent between 1967 and 1987, compared with 2.7 percent for all manufacturing.[1] Over this period, output rose 4.9 percent a year while employee hours rose 0.6 percent. Average annual growth rates between the two subperiods defined below differ markedly with regard to output and employee hours:

| *Period* | *Output per employee hour* | *Output* | *Employee hours* |
|---|---|---|---|
| 1967–87 | 4.3 | 4.9 | 0.6 |
| 1967–79 | 5.5 | 7.5 | 2.0 |
| 1979–87 | 3.8 | 1.0 | -2.7 |

Between 1967 and 1979, output per employee hour increased at an average annual rate of 5.5 percent, more than double the 2.6-percent rate for all manufacturing. Strong demand for such products as plain paper copiers, cartridge-loading cameras, and photographic film caused output to rise 7.5 percent a year. This strong demand was fueled by favorable demographic trends, increases in personal disposable income and leisure time, and a diverse market for photographic equipment and supplies. To meet this demand, manufacturers added production capacity and increased the number of production workers by 1.4 percent a year.

By contrast, in the 1979–87 period, output per employee hour rose 3.8 percent a year, equal to the rate for all manufacturing. With strong competition from imports of photographic products, industry output rose only moderately. The dominant factor behind this growth in produc-

Stuart Kipnis and Clyde Huffstutler are economists in the Division of Industry Productivity and Technology Studies, Bureau of Labor Statistics.

tivity was a decline in employee hours. This reduction in employee hours was part of a restructuring that a number of the major manufacturers undertook in the 1980's to become more productive and cost effective. Along with a reduction in employment, these manufacturers adopted the latest automation and manufacturing techniques, improved inventory methods and supplier relations, and streamlined their corporate structures to expedite decisionmaking. These changes, though not yet fully implemented, have led to a substantial decline in the manufacturing cost and development time for a number of new products.

## Output

*Employment cuts were part of the industry restructuring during the 1980's.*

The photographic equipment and supplies industry manufactures products which may be classified into two categories: equipment and sensitized materials. Photographic equipment consists of such items as still and motion picture cameras and accessories, audiovisual projectors and screens, and photocopying and micrographic equipment. Sensitized materials include still and motion picture film, photographic paper and chemicals, and x-ray film.

With its array of products, this industry serves a wide range of markets. The consumer market for equipment and sensitized materials—mainly still cameras and film—is enormous, as more than 85 percent of all families own at least one camera.[2] Likewise, demand from the more than 100,000 professional photographers for still and motion picture equipment, and for film, paper, and chemicals, is substantial.[3] Photocopying equipment, once considered a luxury purchase, is found in virtually every office. Other business and industrial uses include storage and retrieval of documents by micrographics and medical and dental diagnostics by x-ray.

Output in the industry rose at an average annual rate of 4.9 percent between 1967 and 1987, compared with 2.4 percent for all manufacturing. This single rate, however, masks the substantial difference in growth rates between the subperiods 1967–79 and 1979–87. Furthermore, year-to-year rates vary considerably due to cyclical swings in the economy and new product introductions.

From 1967 to 1979, output in the photographic industry rose at an annual average rate of 7.5 percent, nearly triple that of all manufacturing. There were a number of factors behind this strong growth. An increase in the percent of the population ages 25 to 44, the most active picture takers, along with a rise in real disposable personal income, contributed to the high demand for amateur camera equipment and film. During this period, the industry was successful in making photography appealing to the mass market with the introduction of inexpensive and easy to operate cameras. This greatly expanded the base of camera owners, leading to an increase in demand for photographic supplies such as film and paper.[4]

Photocopying equipment was the fastest growing product in this industry during the period 1967–79. The demand for copiers, and in particular plain paper copiers (PPC's), was fed by the need for quick, inexpensive, and high-quality reproductions of documents. A major problem that photocopier manufacturers faced in capturing the enormous market for their products was the prohibitive cost of the equipment. This was overcome by liberal rental policies. PPC's became standard equipment for medium- and large-size offices during the 1960's and 1970's, while either PPC's or the less-expensive but poorer quality coated paper copiers were found in an increasing number of small offices.[5]

Growth in output slowed considerably after 1979 to an average annual rate of 1.0 percent, only one-third of the rate for all manufacturing. The past success of the industry played a role in this slower growth. With so many high-quality, long-lasting products already in circulation, it was difficult to persuade businesses and consumers that new purchases were necessary. Against this market saturation, new product introduction was less effective than in the previous decade.[6]

Output growth was further limited by the intensification of competition from a number of sources. Certain consumer electronics products not included in the industry served as substitutes for photographic products. The most notable example of this trend was the 50-percent decline in motion picture cameras produced from 1979 to 1987 due to the popularity of the new video cameras.[7] Furthermore, foreign manufacturers were able to capture a significant share of the domestic market in a number of product lines. Shipments of 35mm cameras, virtually all imported, rose from 2.6 million units in 1979 to 7.7 million in 1987.[8] This was a major factor in the nearly 30-percent decline in still cameras manufactured domestically over this period. This same dominance by foreign manufacturers was evident in new photocopier placements (sales and rentals), especially in the low-cost, low-volume segment of the market where the majority of new placements have taken place since 1979.

Year-to-year movements in output fluctuated considerably throughout the 1979–87 period. In 4 of the years studied, output declined; in 6 of the years, output increased by double-digit per-

Table 1. **Indexes of output per employee hour, output, and employee hours in the photographic equipment and supplies industry, 1967–87**

[1977 = 100]

| Year | Output per employee hour | | | Output | Employee hours | | |
|---|---|---|---|---|---|---|---|
| | All employees | Production workers | Non-production workers | | All employees | Production workers | Non-production workers |
| 1967 | 63.6 | 58.5 | 70.2 | 51.2 | 80.5 | 87.5 | 72.9 |
| 1968 | 65.7 | 62.0 | 70.2 | 54.5 | 83.0 | 87.9 | 77.6 |
| 1969 | 70.0 | 67.1 | 73.4 | 60.7 | 86.7 | 90.4 | 82.7 |
| 1970 | 67.6 | 66.8 | 68.4 | 59.4 | 87.9 | 88.9 | 86.8 |
| 1971 | 72.3 | 73.8 | 70.6 | 62.4 | 86.3 | 84.5 | 88.4 |
| 1972 | 82.9 | 83.3 | 82.5 | 75.2 | 90.7 | 90.3 | 91.1 |
| 1973 | 89.8 | 87.2 | 92.8 | 86.5 | 96.3 | 99.2 | 93.2 |
| 1974 | 95.6 | 92.7 | 98.8 | 94.5 | 98.9 | 101.9 | 95.6 |
| 1975 | 92.9 | 95.7 | 89.9 | 84.6 | 91.1 | 88.4 | 94.1 |
| 1976 | 99.4 | 98.9 | 99.9 | 95.0 | 95.6 | 96.1 | 95.1 |
| 1977 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| 1978 | 110.6 | 110.2 | 111.2 | 112.6 | 101.8 | 102.2 | 101.3 |
| 1979 | 120.6 | 122.3 | 118.8 | 124.7 | 103.4 | 102.0 | 105.0 |
| 1980 | 112.7 | 117.0 | 108.4 | 115.2 | 102.2 | 98.5 | 106.3 |
| 1981 | 111.2 | 115.8 | 106.5 | 116.5 | 104.8 | 100.6 | 109.4 |
| 1982 | 110.2 | 116.5 | 104.1 | 117.3 | 106.4 | 100.7 | 112.7 |
| 1983 | 124.8 | 135.9 | 114.6 | 121.1 | 97.0 | 89.1 | 105.7 |
| 1984 | 131.8 | 139.4 | 124.3 | 125.9 | 95.5 | 90.3 | 101.3 |
| 1985 | 131.1 | 142.3 | 120.4 | 124.4 | 94.9 | 87.4 | 103.3 |
| 1986 | 144.3 | 161.9 | 128.9 | 126.3 | 87.5 | 78.0 | 98.0 |
| 1987 | 153.4 | 176.4 | 134.0 | 128.4 | 83.7 | 72.8 | 95.8 |
| | Average annual rates of change (percent) | | | | | | |
| 1967–87 | 4.3 | 5.1 | 3.4 | 4.9 | 0.6 | –0.2 | 1.4 |
| 1967–79 | 5.5 | 6.1 | 4.8 | 7.5 | 2.0 | 1.4 | 2.6 |
| 1979–87 | 3.8 | 5.2 | 2.4 | 1.0 | –2.7 | –4.0 | –1.4 |

centages. These movements have roughly corresponded with the cyclical growth of the economy. Other factors that affected yearly output rates were the introduction of new products and the improvement of old products.

Three of the four years in which output declined were recession years. In these years, sales of photographic equipment, in particular, were adversely affected by the slowdown in economic activity. With disposable personal income and business profits down, many customers postponed buying new equipment and continued to use their old cameras or photocopiers. The use of either old or new equipment, however, still requires supplies such as film or paper. With the usage of photographic equipment only moderately affected by these economic downturns, demand for photographic supplies remained strong. This served to moderate the decline in industry output.[9]

Increased demand for photographic equipment and supplies brought about by upswings in the economic cycle partially explains the strong rate of growth in a number of years. While sales of new equipment declined during periods of slow economic growth, these purchases, along with those of sensitized materials, increased when the economy strengthened. For example, from 1975 to 1979, real gross domestic product rose nearly 21 percent. Over the same period, output in this industry grew by 47 percent.

Besides the health of the economy, the strength of output growth in many of the years covered can be attributed to the industry being able to avoid the output-depressing effects of market saturation. The very nature of the industry, with its array of products manufactured and markets served, has kept output high. Slumps in demand for a particular product or from a single market, when not related to an economic downturn, have not affected output growth significantly. The continued high demand for *other* products or from other markets has prevented industry output from falling significantly.[10]

Introduction of new products, along with continuous improvement of old products, has been effective in countering market saturation and keeping demand high. The prime example of a completely new product leading to an increase in output was the pocket instamatic camera.[11] In 1972, the year this new product was introduced, output of still cameras increased by 59.1 percent. This was the dominant factor in the 20.5-percent increase in industry output. The next

year, with sales of this camera remaining high, still camera output and industry output rose by 28.7 percent and 15.0 percent, respectively.

Introductions of totally new products, however, are rare. More common is the ongoing process of product refinement. Plain paper copying machines and photographic film are excellent examples. The basic technology used in each product was developed prior to 1967: in copiers, electrostatic charges to transfer an image, and in film, light-sensitive silver halide crystals to form the image. To maintain user interest in an increasingly mature market, manufacturers of copiers have continually improved their product. This evolutionary process, using microprocessor, laser, and fiber optic technology, has changed photocopiers from basic copying machines to complex machines able to perform a number of functions, such as self-diagnostics, multiple-size duplication, and communications with computers and other office equipment.[12] Likewise, advances in film building technology have led to marked advances in film speed, fineness of grain, and sharpness of image, maintaining user interest in silver halide photography. The improvement of these and other photographic products and the introduction of new products have been key factors in keeping demand high for photographic equipment and supplies.

*Introduction of new products and refinements of existing ones have helped keep demand high.*

## Employment

Employment in the photographic equipment and supplies industry increased at an annual average rate of 0.6 percent from 1967 to 1987, compared to a 0.1-percent decline for all manufacturing. Over the period 1967–79, industry employment rose from 103,600 persons to 134,200, an annual average increase of 2.1 percent. This growth continued until 1982, with employment peaking at 140,200 persons. Large-scale cutbacks in employment during 1983–87 reduced the number of employees to 107,800. Overall, from 1979 to 1987, employment declined by 2.8 percent a year. For all manufacturing, employment rose by 0.3 percent a year in the 1967–79 period and fell by 1.1 percent annually from 1979 to 1987.

Between 1967 and 1979, movements in industry employment followed fluctuations in output. Chart 1 shows the close relationship between employee hours and output. In all but one of the years in which output rose between 1967 and 1979, employee hours grew because of increases in average weekly hours along with the addition of new workers. In 1975, with output falling significantly, employee hours experienced a large decline as employers reduced both hours worked per week and numbers of workers employed.

In 1970 and 1971, the only years in which output and employee hours moved in opposite directions, a substantial number of hours were being devoted to the development of new products. Manufacturers hired more nonproduction workers, such as engineers, than production workers. This was reversed in 1972 with the introduction of the 110 still camera system, requiring large-scale increases in production worker hours.

A sharp reduction in the level of employment, rather than changes in output, was the dominant factor influencing employee hours during 1979–87. The major manufacturers viewed work force reductions as a necessary step in the successful implementation of sophisticated manufacturing technologies. Thus, this reduction in industry employment was an integral element in the overall effort to boost productivity and lower manufacturing costs.[13]

These cutbacks affected both production and nonproduction workers. With the introduction of automated equipment and computer integrated manufacturing, production worker hours fell by 28 percent from 1982 to 1987, an annual average decline of 5.7 percent. While production worker hours in this industry have historically been volatile, rising and falling with changes in output, *nonproduction* worker hours rose every year but one between 1967 and 1982. Therefore, the 15-percent reduction in nonproduction workers from 1982 to 1987 is significant. During the 1980's, a number of the major manufacturers reorganized their corporate structures, leading to a decline in managerial and administrative positions. Lower level management, closer to the manufacturing process, was given more responsibility for product decisions. The resulting decrease in the time to bring new products to market was necessary to improve competitiveness.[14]

In 1967, production workers accounted for 55 percent of all employees in the industry. From 1967 to 1987, production workers declined by 0.3 percent a year while nonproduction workers increased by 1.5 percent. Thus, by 1987, the proportion of employees classified as production workers was only 43 percent. The corresponding ratio for all manufacturing also fell during this period, but remained substantially greater than that for the photographic industry: 74 percent in 1967 and 68 percent in 1987.

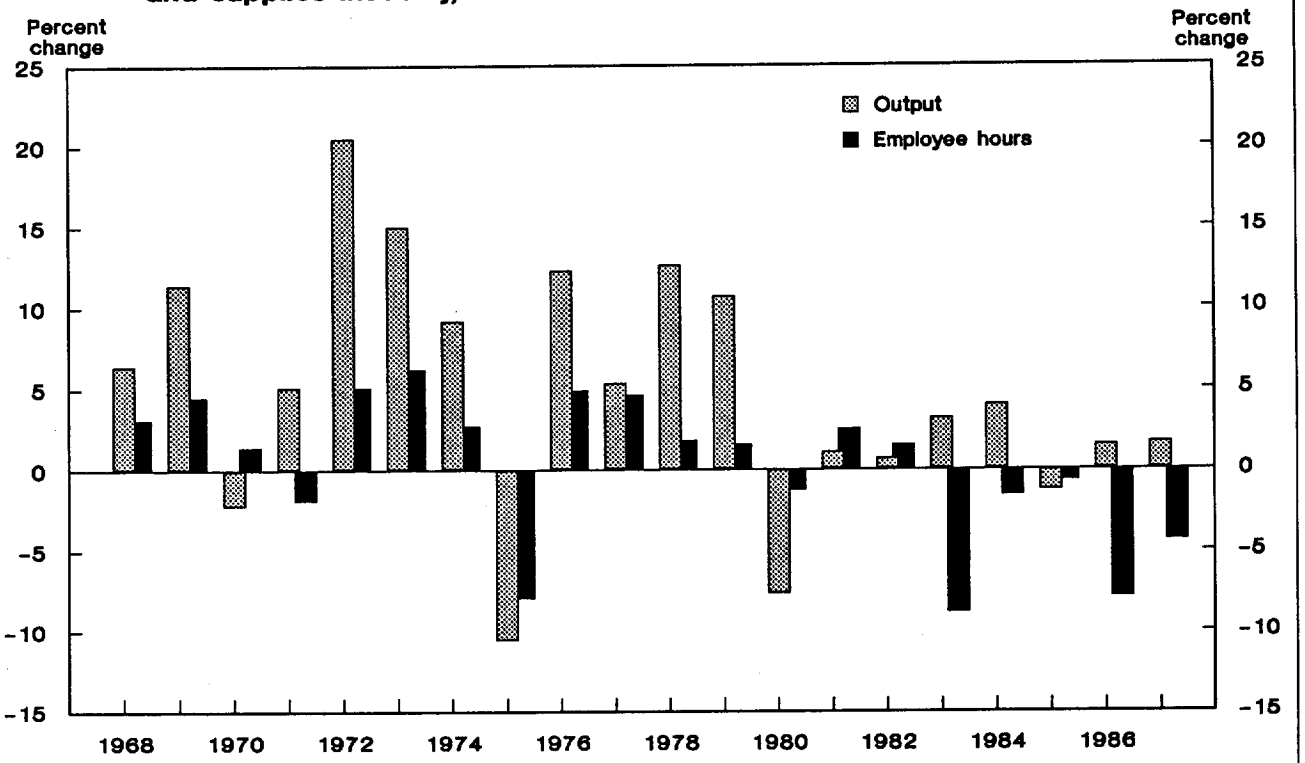
Table 2 compares employment by occupation in the photographic equipment and supplies industry and in all manufacturing for 1986. The industry's particularly high proportion of engi-

neers, scientists, and technicians—over twice the percentage for all manufacturing—reflects the highly technical nature of the development and manufacture of photographic products. Despite reductions during the 1980's, managerial and administrative workers remain a major component of all employees. While retail outlets sell much of this industry's output, there are notable exceptions. In the highly competitive photocopying and micrographic equipment market, domestically manufactured products, unlike most imports, are usually sold directly to the customer. Therefore, marketing and sales personnel, although only 2.5 percent of employment, are very important in this industry.

The comparatively low proportion of production workers reflects the high capital intensity of the industry, especially in the manufacture of sensitized materials.[15] Another factor lessening the need for machinists and other production workers is the industry's substantial level of outside purchases of such goods as plastic and metal parts. However, the industry does employ many assemblers and other handworkers, as the manufacture of photographic equipment involves a great deal of manual assembly. In comparison with all manufacturing, there is a higher percentage of skilled employees, such as precision assemblers and product inspectors, employed in the industry.[16] This is due to the advanced technology used as well as the need for extreme accuracy in the manufacture of photographic film and paper. The relatively small physical size of the material inputs and of the final products contributes to the low percentage of material movers employed.

During the 1980's, the adoption of sophisticated technology by the major manufacturers had an impact not only on the number of production workers but also on their function. For example, the industry traditionally has had a separate staff responsible for inspection. Now, however, workers using computers are increasingly involved in their own quality control. In addition, the use of computers in the design and the manufacture of products has made it even more important for workers to become computer literate. Automated equipment has reduced the direct involvement of workers in the manufacturing process. Instead, workers must ensure that this complex equipment functions properly. Furthermore, the input of production workers has become a vital element in the effort by research and development personnel to design

Chart 1. **Changes in output and employee hours in the photographic equipment and supplies industry, 1967–87**



products for easy assembly.[17] While only recently having an impact on the role of workers, it is apparent that these changes will eventually affect a majority of the industry's work force.

## Industry structure

The two categories of products manufactured in the industry, sensitized materials and photographic equipment, require vastly different technologies in their production. These differences have important effects on industry structure. The manufacture of sensitized materials, requiring extreme precision, is highly capital intensive. The great initial expense of the capital equipment, along with the long lead time from product development to manufacture, precludes entry into this field for all but the largest companies. In 1982, the eight largest companies in the industry accounted for 97 percent of the total value of shipments of photographic film, the largest component of sensitized materials. By contrast, hundreds of companies are active in the more labor-intensive manufacture of equipment. Still, the major innovators of photographic equipment are the few very large companies, reflecting the need to commit large expenditures to research and development. Furthermore, due to the technological interdependence between photographic equipment and sensitized materials, most of the large companies are active in both fields.[18]

In comparison to all manufacturing, the photographic equipment and supplies industry is characterized by a high degree of manufacturing concentration among a few very large companies. This is illustrated in table 3, which shows the 1982 percent distribution of establishments, employment, and value of shipments in the industry and in all manufacturing by establishment size.

From 1967 to 1982, the photographic industry increased from 505 companies to 723. Over the same period, the number of physical establishments grew from 557 to 795. This growth was reversed between 1982 and 1987, as the number of establishments fell to 779. The reorganization of many of the major manufacturers, along with lower than expected demand and strong foreign competition, resulted in a sharp drop in employment levels.

With only 17 percent of the establishments, the State of New York accounted for 54 percent of industry employment, 59 percent of value shipments, and 65 percent of value added in 1977. Other major manufacturing centers are located in California, Illinois, Massachusetts, and New Jersey.

## Capital structure

The manufacture of photographic products, especially sensitized materials, requires a high degree of mechanization and automation. Increases in production capacity as well as improvements in manufacturing efficiency have required large expenditures for new plants and equipment. The high level of capital asset accumulation over time is an indication of the capital intensity of this industry. For example, the ratio of fixed assets per production worker was at least 1.5 times the corresponding level for all manufacturing in every year but one from 1967 to 1986.

Much of the expenditure on new plant and equipment during the 1970's went to expand manufacturing capacity. There was little pressure to introduce new production technology. This changed during the 1980's, as competition from foreign manufacturers in such product lines as photographic film and paper and photocopiers intensified. To remain competitive, it became necessary for domestic producers to introduce advanced automated equipment and computers into the production process. These expenditures on sophisticated equipment were a major component of the restructuring undertaken by a number of the very large manufacturers in the 1980's.[19]

## Research and development

Expenditures on research and development have been extremely important in maintaining strong growth in the photographic industry. The introduction of new products and the improvement of old products have helped maintain user interest in an increasingly mature market. Some innovations, such as the instant camera, were

Table 2. **Percent distribution of employment by occupation for all manufacturing and for the photographic equipment and supplies industry, 1986**

| Occupation | All manufacturing | Photographic equipment and supplies |
|---|---|---|
| Total | 100.0 | 100.0 |
| Managerial and management related occupations | 8.1 | 13.8 |
| Engineers, scientists, and technicians | 7.6 | 16.6 |
| Marketing and sales occupations | 3.0 | 2.5 |
| Administrative support occupations | 11.8 | 16.9 |
| Blue-collar worker supervisors | 4.2 | 4.2 |
| Mechanics, installers, and repairers | 4.2 | 3.1 |
| Precision production occupations | 9.2 | 7.6 |
| Machine setters, operators, and tenders | 22.9 | 14.6 |
| Assemblers and other handworking occupations | 12.1 | 11.8 |
| Various material movers and other laborers | 11.4 | 3.2 |
| All other occupations | 5.5 | 5.7 |

developed within the industry. Other technologies have been developed elsewhere and adapted for industry use. These include microprocessors, fiber optics, and lasers used in micrographic and photocopying equipment.[20] To improve competitiveness, product designers have begun to interact with engineers, shop-floor managers, and assembly workers to create products designed for assembly.[21] Because of the expense of developing and manufacturing new and improved products, as well as the sophistication of the technology used, the major manufacturers perform most research and development. That 2 of the 12 domestic manufacturers with the largest research and development budgets are in the photographic industry is an indication of the importance of such expenditures in the development of photographic products.[22]

## Technology

The technologies used in the manufacture of photographic equipment and of sensitized materials differ greatly. The production of photographic equipment is a labor-intensive process in which manufacturers have only recently adopted automation and other advanced technologies. On the other hand, manufacture of sensitized materials is highly capital intensive due to the exacting standards required. While these differences in methods of production require covering the two product categories separately, it is important to remember their interdependence in the overall photographic system from product development to final usage.

*Sensitized materials.* The two major components of sensitized materials, film and paper, are manufactured by very similar processes. The major difference is in the base used. Photographic paper base is made by a method similar to that used for other papers.[23] However, the need for a chemically pure final product requires special care to ensure freedom from any impurities and contaminants such as metals, bark, and wood dirt.[24]

Cellulose acetate is the most common foundation for film base. Solvents are mixed with cellulose acetate to form a honey-like substance called "dope." After being purified, the dope is piped in a constant flow through a very narrow slot onto a large coating wheel. The need for uniformity of thickness in the extremely thin film base is paramount. The solvents either evaporate as the wheel rotates or are removed by circulating air around the drying sheet. The film base is then rolled and is ready for coating.

The film emulsion consists of gelatin containing suspended crystals of silver halide. Gelatin, made from animal bones and hides, is dissolved in purified water and then agitated in large vessels. During this agitation, a light-sensitive silver halide solution and other chemicals are introduced in very precise increments. Any variations from the desired mix will affect the characteristics of the final product. In the past, obtaining uniformity between batches has been a costly problem. Defective mixes have resulted in labor time being expended to extract the silver from the emulsion and repeat the procedure. Process control computers are now increasingly being used to regulate the manufacture of emulsion and should lead to a reduction in defects. After additional steps, in which the emulsion is further treated to obtain the desired photographic properties, it is ready to be coated onto the base.

Before the application of the emulsion, both film and paper base must be treated to improve the adhesion of the emulsion. This also increases the wet strength of the final product, which is important to its being able to withstand rigorous treatment in photoprocessing solutions. The equipment used in this initial coating stage is similar to that used in the application of emulsion. Nearly all photographic paper is coated with layers of polyethylene, a polymer known for its chemical inertness, water impermeability, and adhesiveness. The chemical properties of the particular polyethylene applied determine the surface texture of the final print: glossy, semi-matte, matte, and textured.

Manufacturers coat film base on both sides with a substance that improves the strength of the film before and after processing. A gelatin layer is then applied to the underside of the base to prevent blurring of the exposed film caused by reflection of light through the emulsion. Also, the gelatin prevents the film from curling during and after processing.

***Today, integrated circuits and microprocessors are widely used in the more sophisticated products.***

The coating of both film and paper base with the light-sensitive emulsion is done in the dark. Operators unwind the base onto long machines where the melted emulsion is floated up to one side of the base and an airknife blows off excess emulsion. To ensure that the photographic film or paper has the proper properties, the emulsion layers must not deviate from the desired thickness by more than a tiny fraction of an inch. Film and paper manufacturers have recently installed a 100-percent testing procedure using infrared scanners to monitor coating accuracy. This replaces the time-consuming and labor-intensive process of checking a few feet from each roll. After being dried in a cooling chamber, the now sensitized film and paper is rewound and sent to be cut and packaged.

Given the increased competition from foreign manufacturers, there has recently been extensive capital investment in sensitized materials manufacturing by U.S. producers. While the basic technology and process have remained the same for decades, the addition of process control computers and infrared scanners, for example, has made it possible for output to rise while employment is being cut. Quality control measures have led to significant declines in product defects. Furthermore, production of photographic film and paper has become more flexible, allowing for quick changeovers from one product to another and the cost-efficient production of low-volume runs. Material handling, traditionally the most labor-intensive activity in sensitized materials manufacturing, is just now being automated.[25]

*Equipment.* The manufacture of photographic equipment involves a number of technologies found in other industries. Due to the great expense of acquiring the capital equipment used to manufacture the many diverse components of photographic equipment, it is common not only for small and medium, but also for large and very large manufacturers to purchase a high proportion of these parts from outside suppliers. These include the metal frames of photocopiers, the plastic bodies of cameras, and the microprocessors of the more advanced equipment.[26] Efforts to lower costs of production and improve productivity in the industry have focused on the manufacture of the components as well as on the final assembly of the equipment.

Product designers have worked closely in recent years with outside vendors, as well as with floor managers, assemblers, and engineers, to simplify equipment assembly. Input from these sources has led to a number of laborsaving modifications in equipment design. For example, a switch on a photocopier was simplified from seven parts to two, resulting in a reduction in assembly time from 77 seconds to 7. Improved design also lowers material costs. A printer head with a new snap-fit design saved 50 percent in material costs and 40 percent in manufacturing time over the old design.[27]

An aspect of product design that manufacturers implemented to improve the capacity of the final product and to simplify assembly was the use of integrated circuits and microprocessors in the more technologically advanced equipment. First used in photocopiers in the mid-1970's and later applied to other equipment, this technology replaced a multitude of mechanical parts. The result was an overall decline in the number of components used and a reduction in assembly time.[28]

During the 1980's, the large manufacturers have used computer-aided design (CAD) extensively in the design and development of photographic equipment. The use of CAD has significantly reduced the time spent designing new products. Furthermore, revisions in design, either to correct an error or adapt a product to a specific market, are handled easily with CAD. Computers enable the designer to interact in the initial stages of product development with suppliers, whether external or internal. By using CAD, parts manufacturers can design production tools nearly simultaneously with the design of the product, further reducing the time required to bring a new product to market.[29]

Manufacturers have also used computers in the production of equipment components and in the final assembly of these parts and subassemblies. The use of computers to track inventory levels, together with the adoption of automated material handling equipment, has allowed manufacturers to reduce the number of workers involved in material handling and the number of days that inventory is held. The application of statistical process control to the quality control process has led to large-scale reductions in product defects and a correspond-

Table 3. **Percent distribution of firms in the photographic equipment and supplies industry and in all manufacturing, by selected characteristics, 1982**

| Average establishment employment | Establishments | | Employment | | Value of shipments | |
|---|---|---|---|---|---|---|
| | Photographic equipment and supplies | All manufacturing | Photographic equipment and supplies | All manufacturing | Photographic equipment and supplies | All manufacturing |
| Total ..... | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| 1 – 19 ..... | 63.6 | 66.1 | 2.6 | 7.9 | 1.7 | 5.0 |
| 20 – 99 ..... | 24.8 | 24.0 | 7.3 | 20.5 | 4.8 | 16.3 |
| 100 – 999 ... | 9.8 | 9.3 | 19.2 | 46.4 | 15.8 | 47.8 |
| 1000 or more . | 1.8 | .6 | 70.9 | 25.2 | 77.7 | 30.9 |

ing decrease in labor time expended on reworks of poor quality output.[30] Computer-aided manufacturing (CAM) is used in the programming of automated machinery. In an integrated CAD/CAM system, manufacturers are able to use more-flexible manufacturing techniques, allowing for cost-effective, low-volume product runs. For example, a computer-controlled robot can now perform in just 15 minutes a die changeover that once took 6 to 10 hours.[31]

Use of computers and automated equipment has proven to be most successful when combined with a strategy to simplify the product, the process, and the organization. Therefore, the utilization of advanced technology by many large manufacturers of photographic equipment is not an isolated occurrence. Instead, these investments are an integral part of the broad restructuring plans adopted to improve productivity and competitiveness.[32]

The high labor requirements of photographic equipment assembly have made this one area of the production process in which manufacturers have implemented a number of changes designed to boost productivity. For instance, manufacturers have concentrated on the simplification of product assembly, the improvement of quality through statistical process control, and the continuous tracking of inventory by computers. These changes have substantially improved the efficiency of equipment assembly, as well as that of parts manufacture. Still, assembly remains highly labor intensive, as automated equipment is not yet suitable for most of the delicate operations required in assembly. Instead, manufacturers have introduced a variety of assembly processes based on the multitude of products manufactured, ranging from disposable cameras with 21 parts to photocopiers with nearly 5,000.

Complex equipment, such as photocopiers and microfilmers, is increasingly being assembled using a series of workstations. Rather than having each assembler perform discrete steps as in a traditional assembly line, workers at these stations execute a number of assembly, as well as nonassembly, tasks. For example, at each station, workers attach various subassemblies and components to the mainframe. Before sending the mainframe to the next station, the assemblers perform a quality check. This is important in locating problems immediately and at their source. The complex flow of components to the various workstations is handled by inventory control computers at each station. Unlike traditional lines, which are best suited for high-volume runs of a single product, assembly by workstations can accommodate changes in subassemblies or components without long delays. With the increasing need to adapt products to specialized markets, this flexibility is highly desirable.[33]

Workstations have also proven effective in the assembly of less complex equipment, such as cameras and basic microfilmers. In the assembly of these machines, frequently only one workstation is needed. This focuses responsibility for all of the functions associated with assembly on a small group of workers or even on a single individual working unaccompanied. With this increased accountability, there has been a dramatic improvement in the quality of the output as well as a reduction in nonassembly workers involved in inventory control and product inspection.[34]

The use of traditional assembly line techniques is most effective in high-volume production runs, where changes in parts and subassemblies are few. The final assembly of a still camera with 225 components involves 10 workers. Assembly takes only 18 minutes, with each worker executing a discrete step along the line. The assemblers perform quality control checks on a random basis at various points on the line. Design-for-assembly programs, which reduce the number of parts used and simplify assembly, have enabled assembly lines to remain a cost-effective technique.[35]

Equipment manufacturers have adopted automated assembly techniques for a few products, the most notable being the disposable camera. Consisting of just 21 parts, this product was designed to be assembled by two automated assembly lines. There are no fasteners, which are difficult for automated equipment to handle. Instead, all parts are engineered to snap and fit together. The use of computers in the design and automated equipment in the manufacture of this camera has allowed for its low-cost production.[36] Still, despite the success of automation in the assembly of the disposable camera, the assembly of most equipment remains heavily labor intensive.

*Computer-aided design helps producers target specific markets.*

## Outlook

Competition from electronic products not classified in the industry and from imports of photographic products should continue to affect output in the U.S. photographic equipment and supplies industry. Introduction of new products and improvement of existing products will remain essential in countering this strong competition. It is expected that significant product advances will include "intelligent" copiers with the capacity to communicate with other office products and photographic film with improved speed, grain, and sharpness.[37]

One product expected to have a significant impact on the photographic industry in coming years is the electronic still camera. These cameras electronically record, on magnetic discs, images that may be viewed and transmitted instantly without chemical processing. At present, photojournalists are the primary users of these cameras, as the importance of their transmitting images quickly is paramount.

A number of obstacles must be overcome before electronic cameras are likely to be widely accepted in the important consumer market. These cameras are currently very expensive. The quality of the color hard-copy prints produced from the magnetic discs is much poorer than that of traditional 35mm prints. Furthermore, with the enormous base of conventional cameras in circulation, it will be difficult to persuade consumers to purchase an entirely new system. Thus, many experts feel electronic photography will not replace conventional photography. Instead, the dominant view is that the two systems will coexist in the form of combination units, with aspects of both formats.[38]

The ability of manufacturers to continue to lower production costs will be essential in order to compete successfully with photographic imports and with substitute products. The introduction of computers and automated equipment, in combination with important modifications in such areas as corporate decisionmaking, inventory control, and employee training, was a significant factor in productivity growth during the 1980's. That manufacturers implemented these changes as part of broad, corporate-wide restructuring plans, rather than in isolation, should allow for the efficient use of advanced technology in the future. □

## Footnotes

[1] The 1987 *Standard Industrial Classification Manual* of the U.S. Office of Management and Budget defines the Photographic Equipment and Supplies Industry and classifies it as SIC 3861. The major products included are (1) photographic apparatus, equipment, parts, attachments, and accessories, such as still and motion picture cameras and projection apparatus; photocopy and microfilm equipment; blueprinting and diazotype (white printing) apparatus and equipment; and other photographic equipment; and (2) sensitized film, paper, cloth, and plates, and prepared photographic chemicals for use therewith.

Average annual rates of change shown in the text and tables are based on the linear least squares trend of the logarithms of the index numbers. The indexes for productivity and related variables will be updated annually, and published in the annual BLS bulletin, *Productivity Measures for Selected Industries and Government Services.*

[2] *1986–87 Wolfman Report on the Photographic and Imaging Industry in the United States* (New York, ABC Leisure Magazines, Inc., 1987), p. 46.

[3] *1986–87 Wolfman Report,* p. 85.

[4] Richard M. Blassey and Jerome Deitch, *The U.S. Photographic Industry: 1963–73, an Economic Review* (U.S. Department of Commerce, 1976), pp. 8–9.

In 1980, 47 percent of amateur still film was used by people ages 25 to 44, according to the *1981–82 Wolfman Report,* p. 32.

In 1965, 24.1 percent of the population was between 25 and 44 years old. This proportion fell slightly to 23.6 percent in 1970 and then rose steadily to 27.8 percent by 1980. See U.S. Department of Commerce, Bureau of the Census, *Statistical Abstract of the United States 1970* (Washington, Government Printing Office, 1970), p. 8; and *Statistical Abstract 1986,* p. 26.

Real disposable personal income in 1982 dollars rose from $1,668 billion in 1970 to $1,932 billion in 1975, and to $2,214 billion in 1979. See *Statistical Abstract 1987,* p. 423.

[5] "Mature Market Forging Ahead," *Financial Times Survey: Reprographics,* Apr. 2, 1980, p. 27.

[6] Mike Antoniak, "Industry to Roll with the Changes," *Photographic Trade News,* Sept. 5, 1988, p. 12; Thomas D. Henwood, "Henwood Analyzes Industry Performance, Future Trends," *Photo Weekly,* Apr. 30, 1984, p. 1; and U.S. Department of Commerce, International Trade Administration, *1986 U.S. Industrial Outlook* (Washington, U.S. Government Printing Office, 1986), p. 35–1.

[7] Video camera shipments rose from 61,000 units in 1979 to 448,000 in 1984. Shipments of the more versatile camcorders, also classified in SIC 3651, were 517,000 in 1985 and 1,604,000 in 1987. Source: Electronic Industry Association.

[8] *1988–89 Wolfman Report,* p. 22.

[9] Blassey and Deitch, *The U.S. Photographic Industry,* p. 12; and *1976 U.S. Industrial Outlook,* p. 271.

[10] *1989 U.S. Industrial Outlook,* p. 33–1.

[11] Blassey and Deitch, *The U.S. Photographic Industry,* p. 11.

[12] Robert Anderson, "The Revolution in Reprographics," *Modern Office Procedures,* November 1982, p. 61.

[13] "The New Lean, Mean Xerox: Fending Off the Japanese," *Business Week,* Oct. 12, 1981, pp. 126–28; and Thomas Moore, "Old-line Industry Shapes Up," *Fortune,* Apr. 27, 1987, p. 23 and pp. 26–28.

[14] "The Shrinking of Middle Management," *Business Week,* Apr. 25, 1983, p. 54.

[15] The manufacture of sensitized materials has traditionally been capital intensive due to the exacting standards required. Equipment manufacture, on the other hand, is labor intensive. Only in the last decade have automation and other advanced technologies such as CAD/CAM been applied to the manufacture of components for photographic equipment. Final assembly remains highly labor intensive. See sections on industry structure and on technology for more detailed coverage.

[16] The percentages of precision assemblers and product inspectors in the photographic industry are 3.95 and 3.97, respectively. For all manufacturing, these figures are 1.81 and 3.05.

[17] Halbert Harris, "Design for Profitable Manufacturing," *Appliance Manufacturer,* September 1987, p. 21; "Leadership Through Quality," *Appliance Manufacturer,* November 1988, p. 43; and industry source.

[18] Blassey and Deitch, *The U.S. Photographic Industry*, pp. 14–17.

[19] "Kodak plans 46% Rise in '85 Outlays, Seeks to Boost Productivity," *The Wall Street Journal*, Dec. 21, 1984, p. 26; Michael C. Gabriele, "Kodak Shoots for Competitive Niche," *Metalworking News*, Mar. 28, 1988, p. 4; and "From Womb to Tomb," *Appliance Manufacturer*, November 1988, pp. 40–42.

[20] "The Chip is Only Half the Story," *Financial Times Survey: Reprographics*, Apr. 2, 1980, p. 28; and Anderson, "The Revolution in Reprographics," p. 61.

[21] Harris, "Design for Profitable Manufacturing," p. 21; "Copiers More Productive—by Design," *Appliance Manufacturer*, November 1988, pp. 39–40; and John Holusha, "Beating Japan at Its Own Game," *The New York Times*, July 16, 1989, sec. 3, p. 1.

[22] "The R&D Elite," *Business Week Special 1989 Bonus Issue: Innovation in America*, pp. 66–67.

[23] For information on the technology used in the manufacture of paper, see *The Impact of Technology on Labor in Four Industries*, Bulletin 2228 (Bureau of Labor Statistics, May 1985), pp. 9–19.

[24] Elliott Novak, "Color Paper Sales Grow, Despite Market Maturity," *Photo Marketing*, November 1984, p. 28; and Peter Krause, "Outlook for the Photo Paper Industry Is Good," *Photo Marketing*, December 1980, p. 34.

Due to the exacting specifications required in the manufacture of the ultra-high grade paper base, there were only six main base paper producers in the non-Communist world as of 1984, two of which were located in the United States. Three of these companies, and one in the United States, coat the paper base with light-sensitive emulsion and market the final product. The other manufacturers act as suppliers of unsensitized paper base to companies engaged in the sensitizing of photographic products.

[25] Industry sources.

[26] Information on a number of the technologies used to manufacture components for photographic equipment can be found in the following *Monthly Labor Review* articles: James D. York, "Productivity growth in plastics lower than all manufacturing," September 1983, pp. 19–21; Barbara Bingham, "Instruments to measure electricity: industry's productivity growth rises," October 1983, pp. 14–15; and Horst Brand and Clyde Huffstutler, "Trends in labor productivity in metal stamping industries," May 1986, pp. 16–17.

[27] "Xerox Design Institute Cuts Product Development Time," *Appliance Manufacturer*, November 1987, pp. 25–26.

[28] Ted Wirth, "Three Good Reasons for the Boom in Copying Machine Use," *The Office*, July 1982, p. 129; and "Innovation in the Camera Industry," *Photo International*, November 1984, p. 25.

[29] Gabriele, "Kodak Shoots for Competitive Niche," p. 4; "Copiers More Productive—by Design," pp. 39–40; and "From Womb to Tomb," pp. 40–42.

[30] "How Xerox Speeds Up the Birth of New Products," *Business Week*, Mar. 19, 1984, pp. 58–59; Norm Alster, "An American Original Beats Back the Copycats," *Electronic Business*, Oct. 1, 1987, pp. 56–59; and "Leadership Through Quality," p. 43.

Statistical process control is used at each stage of the manufacturing process to continuously monitor quality control. Workers subject randomly selected parts and components to a series of performance criteria. Computers analyze the results and determine if quality standards are met. Statistical process control allows manufacturers to pinpoint trouble areas at the source.

[31] "From Womb to Tomb," p. 42; and an industry source.

[32] "Smart Factories: America's Turn?" *Business Week*, May 8, 1989, pp. 142–48.

[33] Industry source.

[34] Holusha, "Beating Japan at Its Own Game," p. 1 and p. 8; and an industry source.

[35] Gabriele, "Kodak Shoots for Competitive Niche," p. 4 and p. 46.

[36] *Ibid.*

[37] "Copiers '86," *Administrative Management*, December 1985, pp. 34–36.

[38] Stephen Booth, "See, No Film," *Rolling Stone*, Mar. 9, 1989, p. 113; George Berkowitz, "Electronic Photography Will Not Displace Film," *Photo Weekly*, May 21, 1984, p. 1; and *1988 U.S. Industrial Outlook*, p. 37–2.

## 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 specific base period. Thus, those goods that require more labor time to produce are given more importance in the index.

In the absence of adequate physical quantity data, the output indexes for the industries discussed here were developed using a deflated value technique. The value of shipments of the various product classes was 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 overall output measures. The result is a final output index conceptually close to the preferred output measure.

The employment and employee hours indexes used to measure labor input were derived from data published by the Bureau of Labor Statistics. 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 such factors 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.