

Industry productivity in natural and processed cheese

*Sustained demand, technological improvements
in manufacturing, the use of computers,
and a better use of marketing contributed
to a rise in productivity over the 1972–90 period*

Daniel J. Curtin

Between 1972 and 1990, the natural and processed cheese industry has been affected by three recessions, changing consumer tastes, and consumers' desire for a healthier diet.¹ Yet the industry has maintained a growth rate in productivity of 2.3 percent annually during this 18-year period. Output in the cheese industry advanced at an average annual rate of 4.6 percent and employee hours rose 2.3 percent annually. The use of computers, improvements in mechanized cheese making systems, and a consolidation of the industry have contributed to the industry's rising productivity.²

Six annual downturns in productivity and three declines in output in the industry occurred during the 1972–90 period studied. Productivity trends are divided into two separate periods—1972–79 and 1979–90. As table 1 shows, a period of modest productivity growth in the 1972–79 period was followed by more substantial growth over the 1979–90 period.

Between 1972 and 1979, the industry felt the effects of the 1973–75 recession. While output did not decline during the 1973–75 recession, its rate of growth slowed. During the 1979–90 period, output, hours, and productivity rose.

Output and demand

Three primary markets for cheese products are food service or restaurants, ingredients in other products, and retail grocery stores. Sales to the

food service industry have expanded rapidly because of increasing popularity of fast food outlets. For example, production of mozzarella cheese, one of the main ingredients in pizza, increased more than 400 percent in the past 15 years.³ The use of cheese as an ingredient in other foods has increased rapidly over the 1972–90 period and this trend is expected to continue. In 1986, 251 new products using cheese as an ingredient were introduced into the market. The largest use of cheese as an ingredient is in frozen dinners, sandwiches, and pizzas. Cheese also is becoming more widely used in bakery items such as crackers and garlic bread, as well as in snack foods.⁴

Output in the cheese industry increased at an average rate of 4.6 percent a year over the 1972–90 period. The largest increase—11.9 percent—was in the recession year of 1974. In other recession years, 1980 and 1982, output grew by 10.8 percent and 4.3 percent, respectively. The slowing of output that generally takes place in a recession did not materialize in the cheese industry in any of the three recessions between 1972 and 1990.

However, sluggish economic growth affected the industry in 1975, when output slowed to a 2.8-percent rate, and in 1983 when the growth rate slowed to 0.4 percent. Output declined only three times in the 18-year period studied. The largest decline, 2.6 percent, was in 1977. Factors such as changing consumer tastes and innovative marketing by the dairy industry, which introduced new products in response to growing health concerns

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Table 1. **Annual percent changes in productivity, output, and hours in the natural and processed cheese industry, 1972-90**

| Years | Output per employee-hour | Output | Employee hours |
|---------------|--------------------------|--------|----------------|
| 1972-73 | 1.2 | 3.2 | 2.0 |
| 1973-74 | 9.0 | 11.9 | 2.8 |
| 1974-75 | 2.7 | 2.8 | .0 |
| 1975-76 | .3 | 7.4 | 7.1 |
| 1976-77 | -5.4 | -2.6 | 2.8 |
| 1977-78 | -1.1 | .7 | 1.8 |
| 1978-79 | .6 | 5.0 | 4.3 |
| 1979-80 | 5.4 | 10.8 | 5.1 |
| 1980-81 | 11.9 | 11.4 | -.4 |
| 1981-82 | 2.5 | 4.3 | 1.7 |
| 1982-83 | -3.9 | .4 | 4.5 |
| 1983-84 | -3.1 | -1.3 | 1.8 |
| 1984-85 | 3.1 | 5.2 | 2.1 |
| 1985-86 | 7.4 | 8.8 | 1.4 |
| 1986-87 | 7.1 | 10.0 | 2.7 |
| 1987-88 | -1.0 | .7 | 1.8 |
| 1988-89 | -1.5 | -1.0 | .4 |
| 1989-90 | 7.4 | 6.3 | -1.0 |
| 1972-90 | 2.3 | 4.6 | 2.3 |
| 1972-79 | 1.0 | 4.0 | 3.0 |
| 1979-90 | 3.1 | 5.0 | 1.8 |

among consumers, helped push up demand for cheese.

Per capita consumption of cheese rose 33 percent in the 1972-79 period, giving a strong boost to the industry's output growth.⁵ Cheese sales, particularly specialty cheeses, are correlated with consumer income, and disposable personal income in constant dollars increased approximately 16 percent between 1972 and 1979.⁶ Another contributing factor to cheese sales growth was the large increase in the number of consumers between the ages of 25 and 34, a large age group of per capita cheese consumers.⁷

In addition, dining out at fast food restaurants and consumption of convenience foods have increased as more women have entered the labor force. Cheese is a main ingredient in fast food and convenience foods.

Output growth in the cheese industry accelerated over the 1979-90 period. Only two declines occurred during this period, in 1984 and 1989. Large increases were recorded in 1980, 1981, 1986, and 1987.

The large increases in output also are linked to the continued rise in the price of meat and poultry. Consumers often look to cheese as an alternative source of protein and substitute cheese for meat as cheese costs remain competitive. The industry's concentrated efforts to promote cheese and cheese

products by advertising also has helped bolster the demand for cheese.

Changing consumer tastes have played an important role in the output of the cheese industry. Consumers seeking high quality and a wider variety of cheese have spurred a move toward offering cheeses in delicatessen departments of grocery stores. Cheese is one of the leading products sold in these delicatessens, second only to meat. According to a Cornell University study, consumers are willing to pay more for these higher priced cheeses.⁸ Delicatessen shoppers are, on average, younger than supermarket shoppers in general and have a higher than average income. Coupled with the increase in delicatessen cheese sales is a trend away from producing bland types of cheese and toward more fragrant and spicier cheeses.⁹

Manufacturers have helped keep the demand for cheese steady, responding to concerns over high cholesterol and salt content by developing improved low fat and low sodium cheeses. Emphasis on calorie reduction and lower fat also has spurred the development of a new category of "light" dairy products. In addition, ongoing industry studies examine how to improve the quality, variety, and shelf stability of reduced fat cheeses. The industry has been foremost in promoting new low fat and low sodium cheeses that provide important nutrients and are excellent sources of calcium.

Employment trends

Employment and employee hours in the cheese industry increased at an average annual rate of 2.3 percent from 1972 to 1990.¹⁰ The number of production workers increased an average 2.1 percent annually during this period. (See table 2.) Average weekly hours declined from 40.4 hours in 1972 to 39.6 hours in 1990. By contrast, the number of nonproduction workers increased 3.4 percent annually between 1972 and 1990.

The proportion of production workers to total employment declined slowly but steadily over the period. In 1972, production workers represented 81 percent of total employment; by 1990, they represented 77 percent.

Most of the growth in employment came from an increase in the number of establishments with an average of 100 or more employees. The number of these establishments increased 68 percent between 1972 and 1987, and employment in these establishments increased 63 percent.¹¹ Over the same period, employment also increased 16 percent in mid-sized establishments (those employing 20-99 workers).

Average hourly earnings of production workers in the cheese industry have risen steadily, but historically have been lower than those in total

manufacturing. Average hourly earnings in 1972 were \$3.26, compared with \$3.82 in manufacturing. By 1990, the industry's average earnings of \$9.71 were still below the \$10.83 average earnings in manufacturing.

Although data on the occupational composition of the cheese industry are not available, some insights can be gained from the broader aggregation of dairy products.¹² In 1990, the occupational category of operators, fabricators, and laborers accounted for the largest proportion of all occupations in the dairy products industries. In this group, a decline is projected to occur in the helpers, laborers, and material movers, hand (including hand packers and packagers) occupations by 2005. Because a number of cheese making operations are still performed manually, particularly wrapping and packaging, a decline in this group would indicate a trend toward greater use of automatic equipment in these operations. Technological improvements in equipment used by the industry could lead to productivity growth in the future. The industry already has made advances in cheese making processes and is continuing efforts to improve efficiency through research into better and improved manufacturing operations.

By 2005, employment in the industry's marketing and sales occupations is projected to increase slightly from the 1990 level. This indicates that the industry is continuing to keep the public informed about its products and to promote new products. A small increase in administrative and

managerial occupations also is projected between 1990 and 2005; in contrast, administrative support occupations, including clerical, are expected to decline slightly.

Industry structure

Between 1972 and 1987, the total number of establishments in the cheese industry fell about 26 percent while total employment grew more than 30 percent. The industry historically has consisted of small establishments. As table 3 shows, some consolidation has taken place in the industry. The decline in the number of establishments was most severe for those with between 1 and 19 employees.

The number of these establishments dropped more than 43 percent between 1972 and 1987. The number of establishments with an average of between 20 and 99 employees changed little, registering a decline of less than 2 percent. But the number of large establishments, 100 or more employees, grew significantly, increasing about 68 percent.

While small establishments are a majority of the industry, their proportion dropped from 68 percent in 1972 to 52 percent in 1987. These small establishments accounted for 13 percent of the industry's value of shipments and 15 percent of total employment in 1972, declining to 6 percent of shipments and 8 percent of employment by 1987.

Establishments employing 100 or more persons accounted for slightly more than 5 percent of all establishments in 1972, but accounted for 56 percent of the value of shipments and 48 percent of total employment. By 1987, these establishments represented more than 12 percent of all establishments and their percentage of shipments was 63, representing nearly 60 percent of industry employment. Medium sized establishments (between 20 and 99 employees) did not experience major changes in their industry share or in their proportion of industry value of shipments or employment.

Over the 1972-87 period, the cheese industry's geographical distribution of establishments and employees remained stable. Wisconsin, New York, Illinois, Minnesota, Pennsylvania, and Ohio accounted for the largest concentration of employment and establishments. But from 1972 to 1987, the number of establishments more than doubled in California, and by 1987, California had the second largest number of the industry's establishments. The production of cheese in the State, which is home to the largest population in the Nation with an ever-growing market for cheese, has nearly quadrupled in the last 10 years. By 1987, California became the second largest milk producing State, providing an increasing supply of lower

Table 2. **Number of employees, production workers, and nonproduction workers in the natural and processed cheese industry, 1972-90**

[In thousands]

| | All employees | Production workers | Nonproduction workers |
|----------|---------------|--------------------|-----------------------|
| 1972 ... | 27.4 | 22.2 | 5.2 |
| 1973 ... | 27.8 | 22.5 | 5.3 |
| 1974 ... | 28.4 | 22.6 | 5.8 |
| 1975 ... | 28.2 | 22.1 | 6.1 |
| 1976 ... | 30.4 | 23.7 | 6.7 |
| 1977 ... | 31.2 | 24.3 | 6.9 |
| 1978 ... | 32.4 | 25.2 | 7.2 |
| 1979 ... | 34.0 | 26.5 | 7.5 |
| 1980 ... | 35.8 | 27.6 | 8.2 |
| 1981 ... | 35.8 | 27.3 | 8.5 |
| 1982 ... | 36.5 | 27.5 | 9.0 |
| 1983 ... | 38.3 | 29.2 | 9.1 |
| 1984 ... | 38.7 | 29.4 | 9.3 |
| 1985 ... | 39.4 | 30.5 | 8.9 |
| 1986 ... | 40.2 | 30.7 | 9.5 |
| 1987 ... | 41.2 | 31.8 | 9.4 |
| 1988 ... | 42.0 | 32.1 | 9.9 |
| 1989 ... | 42.1 | 32.3 | 9.8 |
| 1990 ... | 41.6 | 32.1 | 9.5 |

Table 3. **Number and percent of establishments, employees, and value of shipments in the natural and processed cheese industry, selected years**

| Establishment size | Number of establishments | Percent of all establishments | Number of employees (thousands) | Percent of all employees | Value of shipments (millions of dollars) | Percent of industry's value of shipments |
|-----------------------|--------------------------|-------------------------------|---------------------------------|--------------------------|--|--|
| 1972 | | | | | | |
| Total | 872 | 100.0 | 25.2 | 100.0 | \$3,195.0 | 100.0 |
| 1-19 employees | 591 | 67.8 | 3.9 | 15.5 | 418.0 | 13.1 |
| 20-99 employees | 233 | 26.7 | 9.2 | 36.5 | 982.0 | 30.7 |
| 100 or more employees | 48 | 5.5 | 12.1 | 48.0 | 1,795.0 | 56.2 |
| 1977 | | | | | | |
| Total | 791 | 100.0 | 26.7 | 100.0 | 6,126.0 | 100.0 |
| 1-19 employees | 498 | 63.0 | 3.2 | 12.0 | 619.8 | 10.1 |
| 20-99 employees | 241 | 30.5 | 10.3 | 38.6 | 2,236.6 | 36.5 |
| 100 or more employees | 52 | 6.6 | 13.2 | 49.4 | 3,269.6 | 53.4 |
| 1982 | | | | | | |
| Total | 704 | 100.0 | 29.6 | 100.0 | 10,762.8 | 100.0 |
| 1-19 employees | 385 | 54.7 | 3.0 | 10.1 | 808.3 | 7.5 |
| 20-99 employees | 247 | 35.1 | 10.8 | 36.5 | 4,013.0 | 37.3 |
| 100 or more employees | 72 | 10.2 | 15.8 | 53.4 | 5,941.5 | 55.2 |
| 1987 | | | | | | |
| Total | 643 | 100.0 | 33.0 | 100.0 | 12,947.5 | 100.0 |
| 1-19 employees | 333 | 51.8 | 2.6 | 7.9 | 723.3 | 5.6 |
| 20-99 employees | 229 | 35.6 | 10.7 | 32.4 | 4,056.0 | 31.3 |
| 100 or more employees | 81 | 12.6 | 19.7 | 59.7 | 8,168.2 | 63.1 |

SOURCE: Bureau of the Census, U.S. Department of Commerce.

priced milk to cheesemakers. More than 25 percent of California's milk production is now used for cheese, compared with 13 percent in 1980.¹³

Manufacturing techniques, technologies

The industry manufactures natural cheese, processed cheese, cheese foods and spreads, and cheese imitations and substitutes. Cheese is defined as the concentration of all or part of the components of milk obtained through the coagulation of casein, the major milk protein, by suitable enzymes or by acid produced by bacteria.

Cheese made directly from whole milk is known as natural cheese. Pasteurized process cheese, cheese foods, and cheese spreads are made by blending and heating one or more varieties of natural cheese.

The process of making cheese consists of several steps.¹⁴ It begins when pasteurized milk is pumped into large cooking vats equipped to control the temperature of the milk as the cheese is made. A starter is added automatically to the pasteurized or heat-treated milk soon after the vats are filled. Starters facilitate the production of lactic acid in the milk, controlling the moisture in the

curd and texture of the cheese. When the milk has reached the proper acidity, rennet, an enzyme preparation used to curdle milk, is added.

The curd, separated from the whey, is used at once in unripened cheese. In other cheese, the curd is ripened by the action of beneficial bacteria, molds, yeasts, and enzymes. The curd is cut into cubes when it reaches the proper consistency or firmness. After the curd is cut, heating and gentle stirring with mechanical agitators cause the curd to shrink and become firmer, thus squeezing out some of the whey. When it reaches the proper consistency and acidity, the curd is "ditched" or "trenched;" it is packed against the side of the vat leaving a narrow trench extending down the center to allow the whey to be drained.

Cheese manufacturing techniques differ by type of cheese depending on the composition of the milk used; the type of bacteria or molds used for ripening; the conditions of ripening, such as temperature, humidity, and length of ripening; the time and extent of whey expulsion; the method used to cut and form the curd; the amount of salt used and the method used when adding salt; the degree of pressing and the method used; and the amount of coloring added.

In the manufacture of cheddar cheese, the curd is sliced, turned regularly, and stacked and restacked to induce matting of the curd and expel most of the whey. This turning and stacking is known as "cheddaring."

The manufacture of Italian-type cheeses generally requires a higher temperature than that for cheddar. The curd is formed and stretched in hot water, placed in hoops in cold water, and immersed in salt brine.

The method of manufacturing cheese remained virtually unchanged until technological advances in the industry occurred in the late 1960's and early 1970's.¹⁵ Manufacturers have introduced different types of equipment, mechanizing the cheese making process. The use of mechanized equipment has resulted in labor savings, increased yields, and improved product flow. Because of these advances, manufacturers produce larger quantities of higher quality cheeses at higher speeds and spurred the production of a wider variety of cheese.

Enclosed vat systems used in the initial stages of cheese manufacturing were introduced in the mid-1970's. These new vertical and oval shaped vats increase vat capacity, and offer improved cheese yields of consistent high quality while reducing labor requirements in cheese manufacturing. Vertical and oval vat systems are equipped with blades that rotate in one direction for stirring and reverse for cutting. In recent years, these vats have been integrated with computers that control the sequencing of the vat's operations, such as filling the vat with milk, adding color and rennet. Computers also control agitator speed.

Mechanized systems are now available that mill, salt, and hoop in a continuous stream. Advanced machines mill and salt the curd while other systems mill the curd and move it by a conveyor belt that continuously weighs the curd. The weight of the curd regulates the amount of salt applied; the continuous weighing of the curd eliminates manual salting. For example, in cheddar production, labor requirements have been reduced by 20 percent with these mechanized milling, salting, and hooping systems.¹⁶

Manufacturers use two methods for hooping or forming salted curd. One method of fusing 40-pound blocks uses hoop fillers to fill stainless steel hoops with salted curd. The development of vacuum presses in the 1970's reduced pressing time and allowed a constant temperature to be maintained during the process.

The continuous block forming tower fuses salted curd in a vacuum, avoiding the use of hoops and molds. The filling time takes approximately 30 minutes to fuse and de-whey the curd. The tower can produce a block of cheese every 90 to 120 seconds and may be operated continuously 24

hours a day. The block forming tower simplifies operations by eliminating handling and the intensive labor previously associated with this process. In a large capacity plant, the block forming tower may reduce labor by six persons per shift, and may reduce labor requirements for smaller plants by three or four workers per shift. This new system also reduces loss caused by trimming cheese, and maintains consistency in quality and sanitary standards.¹⁷

In recent years, computers have become an integral part of the cheese manufacturing process. Computers are not only used for accounting purposes but are now used in regulating the flow of raw material that helps maintain the uniformity of the product.¹⁸ The industry also uses computers as management tools for such procedures as work scheduling, maintaining tighter production schedules, inventory control, and monitoring the maintenance of the system. Computers have helped improve trouble shooting capability by quickly pinpointing problems in the system, which reduces idle time. Computers also have enhanced the widely used clean-in-place procedure of cleaning cheese-making equipment. Computers can automatically monitor cleaning solution strengths, temperatures, pressure and cleaning cycles, reducing labor required to clean the equipment and the idle time associated with the cleaning process.¹⁹

In addition, packaging technology has advanced a great deal in the past decade. Cheese in 40-pound blocks can be packaged mechanically using several methods, such as vacuum pouches, heat-shrink bags, and Cryovac packaging systems. After the block has been removed from the hoop or expelled from the block former, it is vacuum sealed into a plastic bag or wrapped in plastic. The cheese block is passed through a shrink tunnel and placed in a cardboard container.

Packaging cheese for retail sale is more labor intensive than packaging block cheese. This type of packaging involves unwrapping, cutting, packaging, weighing, labeling, and packing the cheese in shipping containers. The unwrapping of the cheese and removal from its shipping box are done entirely by hand. This process also involves the removal of any mold on the surface of the cheese. A variety of automated systems is available to carry out the steps of wrapping cheese for distribution to consumers.²⁰

Outlook

Improvements in productivity are expected to continue for the cheese industry. Although it is a mature industry, manufacturers are expected to continue to search for improved cheese making methods and equipment and incorporate these into

the current processes. Major developments in the industry have been and are expected to continue in the areas of cost reduction through reduced material losses, improved automation, or improved energy use. There is a growing need for new processing plants that are versatile and can enable the manufacturer to meet the demand for a wider range of products.²¹ The industry will continue to develop low fat and reduced sodium products in response to consumer demand.

Current research is focusing on developing

an accelerated ripening process, improving the flavor of low fat and low sodium cheeses, creating a faster method of manufacturing cheddar cheese, and making further developments in the continuous cheese making process. Infrared sensors are being tested to control the blending operations that occur early in the cheese making process to maintain quality. Computer use is continuing to become more widespread throughout the industry, particularly fully integrated computer systems. □

Footnotes

¹ The Office of Management and Budget has designated the natural, processed, and imitation cheese industry as SIC 2022 in the *Standard Industrial Classification Manual, 1987*. The industry is comprised of establishments engaged primarily in manufacturing natural cheese (except cottage cheese), processed cheese, cheese foods, cheese spreads and cheese analogs (imitations and substitutes). These establishments also produce byproducts such as raw liquid whey.

All average annual rates of change mentioned in the text and tables are based on the compound interest method of computation. The indexes for productivity and related variables are updated annually and published in the *Productivity Measures for Selected Industries and Government Services* (Bureau of Labor Statistics).

² The productivity indexes for the natural and processed cheese industry represent change over time in the ratio of the weighted outputs of the industry's products to employee hours. A technical note describing the methods used to develop the indexes is available from the Office of Productivity and Technology, Division of Industry Productivity and Technology Studies.

The weighted output indexes use a deflated value technique. Annual output indexes are benchmarked to more comprehensive data available every 5 years in the Census of Manufactures.

Output is defined as the total industry production in shipments and net changes in inventories of finished goods and work in process. Data available from the Bureau of Economic Analysis (BEA) and the Census of Manufactures show that large quantities of natural cheese are purchased from establishments classified in the natural and processed cheese industry. This may lead to double counting the output that could distort the output and productivity indexes. Therefore, an estimate of intra-sectoral shipments was calculated for the industry using data from BEA and the Census of Manufactures. These data were used to adjust the final output indexes for the industry. A more complete description of the methodology used to construct these measures is in the appendix.

³ *Dairy Products, 1987 Summary* (U.S. Department of Agriculture, National Agricultural Statistics Service, Agricultural Statistics Board, May 1988).

⁴ Jerry Dryer, "New Products and New Uses Give Cheesemakers New Life," *Dairy Foods*, Vol. 90, January 1989, pp. 66-67.

⁵ *Statistical Abstract of the United States: 1974* (95th edition), p. 90; and *Statistical Abstract of the United States: 1987* (107th edition), p. 110 (U.S. Bureau of the Census).

⁶ *Statistical Abstract of the United States*, op. cit., pp. 376 and 419. Also, Bureau of Labor Statistics Consumer Price Index for All Urban Consumers, all items, 1982-84=100.

⁷ "Cheeses," *Food Distributors News*, September/October 1973, pp. 7-8.

⁸ John Umhoefer, "Cheese: The Rising Star of the Deli Case," *Dairy Foods*, Vol. 88, July 1988, pp. 35-37, citing Edward W. McLaughlin, Gene A. German, and Michael P. Uetz, *The Economics of Supermarket Delicatessen*, Agricultural Economics Research 86-23, September 1986, Department of Agricultural Economics, Cornell University, Ithaca, NY.

⁹ "Fragrant, Spicier Cheeses Thrive in Booming Dairy Industry," *Food Distributors Magazine*, July 1988, p. 26.

¹⁰ Data pertaining to employment and hours are from *Employment, Hours, and Earnings, United States, 1909-90*, Vol. I, Bulletin 2370, (Bureau of Labor Statistics, March 1991); and *Supplement to Employment and Earnings* (July 1991).

¹¹ 1987 Census of Manufactures, U.S. Department of Commerce, Bureau of the Census.

¹² Data pertaining to the occupational composition of the industry and occupational projections are from "BLS National Industry-Occupational Employment Matrix, 1990 and projected 2005 alternatives."

¹³ John Umhoefer, "California's New Gold Rush," *Dairy Foods*, Vol. 89, January 1988, pp. 37-44.

¹⁴ Jens K. Mesa-Dishington, Richard D. Aplin and David M. Barbano, *Cheddar Cheese Manufacturing Cost Economics of Size and Effects of Different Current Technologies*, Agricultural Economics Research 87-2 and Agricultural Economics Research 87-3, (Ithaca, NY, Department of Agricultural Economics, Cornell University, January 1987).

¹⁵ J. Czulak, "Mechanizing Cheese Making," *CSIRO Fd Res. Q.*, 1974, 34, pp. 40-45. Reprinted from Czulak, J. (1974). "Mechanization and automation of cheese manufacture—a synoptic view," in the Centenary Book of the Christian Hansen Laboratorium S/A, Copenhagen.

¹⁶ N. F. Olson, "Mechanized and Continuous Cheese Making Process for Cheddar and Other Ripened Cheese," *Journal of Dairy Science*, Vol. 58, No. 7, pp. 1015-1020.

¹⁷ *The Wincanton Continuous Block Forming System*, Stoelting, Inc. Dairy Equipment Division, Bulletin No. 1400, 1984.

¹⁸ Clem Honer, "Mega-Cheese," *Dairy Foods*, Vol. 90, December 1989, pp. 58-61.

¹⁹ Jerry Dryer, "A Decade of Development," *Dairy Foods*, Vol. 89, October 1988, pp. 102-110.

²⁰ Clem Honer, "Cheese That's a Cut and Wrap Above," *Dairy Foods*, Vol. 90, February 1989, pp. 61-69.

²¹ K. J. Burgess, Two-Day Symposium, "The Dairy Industry Faces its Market," November 1985, London, *Journal of the Society of Dairy Technology*, Vol. 39, No. 4, October 1986.

APPENDIX: Measurement techniques and limitations

Indexes of output per employee hour measure changes in the relationship between the output of an industry and employee hours expended on that output. The output per employee hour measures relate output to one input—labor time; the measures do not gauge the specific contribution of labor, capital, or any other factor of production. Rather, they reflect the joint effect of a number of interrelated influences 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. An index of output per employee hour is derived by dividing an index of output by an index of industry employee hours.

Output indexes measure the change in industry output over time. The output index for the natural and processed cheese industry was developed using a deflated value technique. The deflated value technique removes the price change from the current dollar value of the industry's production. The value of shipments of the various product classes, obtained from the Bureau of the Census is deflated using appropriate BLS Producer Price Indexes.

Indexes of the constant dollar values at the product class level are combined with employee hour weights to derive an industry quantity of shipments index. This index is adjusted for inventory change and coverage. The change in finished goods and work in process inventories is added to the value of shipments to derive an estimated value of production. The value of production is divided by the value of shipments to obtain an inventory adjustment ratio. A coverage adjustment is made to bring the establishment coded shipments data

up to the level of industry shipments. The quantity of shipments index is multiplied by the inventory and coverage adjustment ratios, resulting in an industry production index.

The annual output index series is adjusted (by linear interpolation) to the index levels of the benchmark output series. The benchmark series produced every 5 years incorporates more comprehensive, but less frequently collected data. The output measure for the natural and processed cheese industry excludes shipments to other establishments in the same industry to avoid double counting. An estimate of intrasectoral shipments is calculated from data in the Bureau of Economic Analysis' input-output tables and the Census of Manufactures. The estimate is derived by dividing the current dollar value of shipments net of intra-sectoral shipments by total current dollar value of industry shipments. These data are used to adjust the benchmark output indexes for the industry.

The employment and employee hour indexes used to measure labor input were derived from data published by the Bureau of Labor Statistics. Employment and employee hour indexes measure the change in the aggregate number of employees or employee hours over a period of time. Employment and employee hours are each considered homogeneous and additive. Therefore, changes in employment, such as in the skills, education, and experience of persons constituting the aggregate are not reflected in the indexes. The employee hour data relate to the total time expended by the employees in establishments classified in the industry, and include hours spent on the production of primary and secondary products.