Technology and Labor in Oil and Gas Extraction and Commercial Banking

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Preface

Some of the major technological changes in two American industries — oil and gas extraction (SIC 13) and commercial banking (SIC 602) — are appraised in this bulletin. This bulletin also discusses the effects of these changes on productivity and labor over the next 5 to 10 years.

This bulletin is one of a series which presents the results of the Bureau's continuing research on productivity and technological developments in major industries. Previous bulletins in this series are included in the list of BLS publications on technological change at the end of this study.

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Contents

Contents—Continued

Page

Chapter 1. Oil and Gas Extraction

Important technological changes are taking place within the oil and gas extraction industry (SIC 13).[1] Offshore production is venturing into deeper water, there are innovations in the recovery of oil in existing reservoirs, and drilling equipment has been improved. Perhaps most significantly, seismic exploring and imaging of the hidden substrata that may bear fossil fuels has undergone dramatic advances in the past decade, and the development of both more powerful workstations and supercomputers that are capable of numerous, simultaneous operations is expected to produce equally impressive advances in oil and gas exploration and resource cataloging during the 1990's. Horizontal drilling and refined seismic array methods also are aiding exploration. These advances can lower costs of finding oil and gas per unit of energy produced.

Sharp fluctuations of oil prices in recent years have caused the oil companies to monitor staffing more carefully. There are continuing efforts to reduce staffing of management, clerical, and professional employees to the most efficient levels. Some of the important breakthroughs in exploration and extraction technology have occurred in research-based enterprises outside of the oil and gas extraction industry. The industry is inclined to rely on outside innovation, since vendors of gas and oil technology relieve the large companies of some costly research and development. As a result of this, and because of a shift in emphasis by major companies to overseas production from new, low-cost oil fields, many research centers have been either scaled back or closed down. This has eliminated many jobs once held by highly trained engineers and scientists. Moreover, the smaller producers often do not have the resources to carry out much innovation, nor to develop new machinery and equipment, so they rely increasingly on software and other support from these new firms.

During the 1980's, many small oil deposits were found, in the United States, but no giant oil fields were discovered. Various wilderness areas that may contain large oil fields remain closed to oil exploration, and some off-shore areas also are closed to exploration and production. Oil production has been declining.

During the 1973-79 period, the BLS index of output per employee-hour in crude petroleum and natural gas production declined over 7 percent per year. Output per employee-hour increased during the second half of the 1980's, but not enough to restore the index to the 1973 level. Output per employee hour declined an average of 3.1 percent a year in the 1973-91 period. As many existing oil fields are near depletion, and more labor per unit of production is often required, it is difficult to increase productivity. The newer fields present significant problems in extracting oil from relatively small reserves.

Exploration economics is controlled by market prices. International market price levels result in part from the production decisions made by major producers within the Organization of Petroleum Exporting Countries (OPEC). During the past decade, high production levels worldwide have maintained prices for oil that makes it financially risky to explore for new reserves in the United States. In 1992, new U.S. oil exploration decreased substantially. During recent years, natural gas prices also have been relatively weak.

The technologies associated with enhanced recovery—the process of extracting oil that cannot be pumped out of the reservoir or helped out by water flooding or natural gas re-injection—are improving. This affects exploration and development by increasing the percent of known oil that is considered recoverable. When market prices fall, drilling and field development can be justified only for those fields with a high proportion of recoverable reserves. Prices have been so weak and the outlook for price rises so unclear that oil field developmental activity and overall capital investment are at a low level and still declining. The average number of drilling rigs in operation was estimated to be 659 in 1992, down over 23 percent from 1991, and the monthly average number of operating seismic crews was estimated at 78 in 1992 in contrast to 104 in 1991 and 182 in 1988.[2] Most of the rigs were drilling in existing fields, or they were drilling to tap gas deposits in coal seams. Extracting gas from coal seams is one area of expansion in the domestic industry. During the rest of the 1990's, gas extraction activity in coal fields is expected to experience significant growth.

Industry experts are hopeful that natural gas demand will rise enough to stimulate exploration and drilling during the coming 10 years. The demand for natural gas is

[1] Standard Industrial classification 13 includes crude petroleum and natural gas, natural gas liquids, and oil and gas field services such as drilling and exploration.

[2] *U.S. Industrial Outlook 1993,* International Trade Administration, U.S. Department of Energy, pp. 3-5.

expected to increase since it is an abundant and relatively clean domestic energy resource.

Environmental and safety requirements have been growing in recent years. This could further inhibit the level of investment and development since these additional costs have to be considered when investment decisions are being made. Moreover, some industry representatives assert that environmental and regulatory issues have been volatile and have added to business planning uncertainty. The industry advocates changes in regulations and tax law that would simplify and reduce the cost of compliance, while increasing confidence levels in future cost projections.

Employment increased at a modest average annual rate between 1973 and 1992, 1.3 percent. The first half of this period was generally a time of rapid employment growth, and the past decade had been a time of relatively gradual employment contraction. The number of workers declined after 1982 due in part to the depressed prices resulting from market abundance of petroleum and natural gas. In 1992, the industry employed 350,300. Of this number, 226,100 were production workers; women numbered 69,000.

Labor-management relations in this industry remain fairly good despite declining employment, safety issues, and training concerns. Unions have gained some bargaining concessions on working conditions, but have had less success restricting the use of non-union, intermittent workers during peak work periods. Benefit and salary levels have tended to keep up with inflation, and more resources are being devoted to issues such as training.

Although there are fewer than 10 very large, integrated oil companies in the United States, there are several independent operators of substantial size and resource. Despite this, the relative financial standing of oil companies among American businesses has declined over the past decade. This reflects the poor financial returns on large capital investments in the early 1980's and the existing price and market conditions that have restricted domestic growth opportunities.[3]

Over 1,400 larger firms are involved directly or through closely related supporting roles in oil and gas extraction. At least 300 of these firms play significant roles in exploration and drilling, and about 100 are highly specialized in support services.[4] During 1992, an additional 6,000 small, independent companies were active in this industry. There were over 15,000 firms involved in oil production in 1986, so the 1992 total of 7,400 reflects the severe decline of domestic activity in oil and gas extraction.[5]

The companies in the oil and gas extraction industry drill, complete, and equip wells. They operate separators, emulsion breakers, and desilting equipment, and they conduct other activities related to exploration and production prior to the shipping and refining stages.

In mid-1992, the United States produced between 7 and 8 million barrels of crude oil per day. Production of natural gas is expected to exceed 17 trillion cubic feet in 1992. Low natural gas prices and the expansion of the Mexican economy have caused exports of U.S. natural gas to Mexico to grow from 15.7 billion cubic feet (bcf) in 1990 to 61.7 bcf in 1991, and the pace of gas exports indicates that Mexico may import more than 100 bcf from the United States in 1992.[6]

Technology in the 1990's

Refinements in measuring instruments and the rapid advance of computer technology are causing significant changes in exploration and field development. The level of discovery risk has fallen. The number of dry holes drilled per discovery has declined for companies using computer-aided exploration. This tends to lower the cost of exploration by reducing the amount of time, equipment, and labor needed to bring a productive well on line. However, the uncertainty of future oil prices has curtailed exploration and development of new domestic fields.

Other significant technology advances in oil and gas extraction include total process integration, better metals, equipment refinements, improved maintenance, horizontal drilling, and the enhancement and expansion of computer applications. Quality and process improvement efforts have frequently been successful and have been crucial in preventing more rapid erosion in domestic oil production.

Exploration technologies

Prior to the 1970's, rock strata was evaluated by detonating explosives and registering the resulting seismic effects at a few set points. This single-point analysis produced only a small amount of useful data. Furthermore, the ability to process seismic data was limited. Oil experts sometimes described these evaluations as more of a "black art" than a science. Explosives gave way to seismic-array air guns and multiple-point sensors. As the amount of information mounted, the use of computers became essential to process the data. The "black art" aspect of exploration began to fade.

Two-dimensional images of rock structures that resulted from single-point explosions gave way to three-dimensional analysis from sequential, and multiple-point

[3] Scott Burns, "Amid Chaos, Only Change Remains Same," *The Dallas Morning News*, June 16, 1992, p. D1.

[4] "*Standard and Poor's Register-1992*, vol.1, pp. 109-113.

[5] "U.S. Independents Search for Oil Abroad," *The Wall Street Journal*, April 20, 1992, pp. A1 and A4.

[6] *U.S. Industrial Outlook 1992*, International Trade Administration, pp. 3-1 - 3-5.

A.D. Koen, "U.S., Canadian Pipelines, Producers, Lining Up to Meet Mexican Gas Demand Growth," *Oil and Gas Journal*, April 6, 1992, pp. 21-26.

air gun detonations. It took several years for data processing capabilities to begin catching up with the new, seismic data acquisition. A new data analysis technology, computer-aided exploration (CAEX), has evolved since 1984 through the development of workstations, supercomputers, software advances, and rapid progress in three-dimensional analysis.

A rapid decline in software and computing costs makes this technology available to smaller firms. The cost of a CAEX workstation system dropped from more than $350,000 in 1986 to less than $100,000 at the end of 1990.[7] Moreover, the color quality and the contrast of the three-dimensional pictures generated of the rock structures continues to improve. Fractal geometry may eventually make it possible to analyze variations in rock porosity within relatively uniform geologic structures. This will make it possible to more accurately estimate the volume of oil and gas deposits, and to assess the difficulty of extracting the deposits.[8] These images are already of sufficient quality to enable skilled interpreters to efficiently pick the cleanest, thickest reservoir take-point (shaft location for extracting the most oil possible) in a given fault block.

As computers have become able to handle the mass of data from multiple-point seismic sensing, the efficiency of seismic operations has grown. In marine exploration, complex signal source and sensor arrays allow scientists to gather significant data on rock structures as remote as 8,000 feet below the ocean floor. This reduces the amount of time and labor needed to produce a thorough seismic analysis.[9]

The present technical level of seismic analysis can increase the ratio of productive wells to dry holes in exploration. Given a 10-percent success rate with cruder analysis techniques, the new methods can raise success rates to a range of 15 to 80 percent, depending on the area and rock structure. Generally, underwater seismic analysis can raise the success rate from about 10 percent to 12 to 15 percent. However, expected advances in signal enhancement, inversion, velocity modeling, amplitude analysis, and geologic modeling should raise the success ratio substantially in the coming few years. Moreover, vertical seismic profiling during drilling operations should reduce the possibility of abandoning a drilling operation short of a probable strike.

In the the near future, wavelet signal analysis will be adapted for oil exploration. This is a more efficient method of analysis, which will allow the same level of data analysis in one tenth the computing time. Data compression techniques may increase this advantage even more and make it practical to use workstations for jobs that presently require supercomputers.[10]

One major consequence of the new seismic analysis technology is that areas of skills and knowledge that used to be professionally distinct are successfully being merged. This new technology is bringing programmers, mathematicians, acoustical scientists, radar imaging experts, hydrologists, geophysicists, and geologists into a broader scientific discipline that may be named "explorationist." Without the advances in seismic data generation and computer analysis the emergence of this integrated field would be impossible.[11] Moreover, the integration of these disciplines is leading to a much higher level of coordination between exploration and field development.

Satellite and aerial photography and laser analysis have begun to play small roles in exploration, and their importance may grow.

Not all the advances in evaluating oil and gas reserves are highly technical. A new method of heating core samples to temperatures equivalent to the stratum from which they came can give a more accurate assessment of reserves.[12]

In addition, programmable logic controllers (PLC's) have recently come into use in onshore oil operations. These digital electronic devices are used to control machines and processes. This technology can reduce the amount of training needed for oil production personnel. PLC's also can simplify the control of inventory management and maintenance operations. Moreover, these devices can aid in trouble shooting and reduce labor requirements. PLC's and related computer technology eventually will be applied to all aspects of field operations, and this will tend to increase operational integration.

Onshore operations

Operational efficiency is improving, and better waste management techniques are being introduced. Equipment improvements are altering maintenance needs at drilling and production sites. The size of the production labor force employed directly by the oil and gas extraction companies is dropping, while the number of workers in oil and gas services is increasing. This is due to the changing nature of oil field work and the way it is carried out. More work is being done by contractors and temporary workers.

Emergency equipment and cutoff-valves have been improved. Pipe and other metal parts are more corrosion resistant than in the past. Basic sucker rod pumping systems have been improved and coiled tubing may reduce material costs in drilling, coring and testing slim hole wells. Using angle changes or bends (doglegs) in drilling increases

[7] Mark Ivey and Richard Melcher, "The CAT Scans of the Oil Patch," *Business Week*, June 10, 1991, pp. 66-67.

[8] L. C. Lawyer, "Trends Providing Value-Added Technology," *Oil and Gas Journal*, November 4, 1991, pp. 50-52.

[9] Thomas C. Hayes, "Zeroing in on Oil Far Below the Sea," *The New York Times*, August 7, 1991, pp. D1 and D7.

[10] John Carey, "Wavelets are Causing Ripples Everywhere," *Business Week*, February 3, 1992, pp. 74-76.

[11] Hugh W. Hardy, "Bringing Geophysical Trends into Sharper Focus," *Oil and Gas Journal*, November 4, 1991 pp. 52-53.

[12] Patrick Bent, Stephen Radford, and Lawrence Owen, "Technique to Reheat Cores Improves Analysis," *Oil and Gas Journal*, December 23, 1991.

the lateral force strength of drilling pipe. Better work techniques tend to limit damage and corrosion in pipe and equipment while increasing material longevity. Plastic coatings, oil-based lubricating mud or low acidity mud, and oxygen scavenging chemicals also reduce corrosion rates in wells. New, better lubricants extend pipe thread life and machinery life.

The use of pump-off controllers and programmable logic controllers are widespread. Integrated automation systems monitor, measure, and control field operations in many production areas throughout the country. These systems free personnel from the necessary but low productivity task of conducting surveillance to find operational problems. Field employees are involved in activities that minimize recurring failures. They are expected to maintain the production process at a high level. So far, new technologies do not significantly reduce labor requirements, but they do improve operations. Advanced equipment and processes require field personnel to have new analytical, technical, and computer skills, and this has caused a fundamental shift in the job demands in producing operations.

Many materials are being recycled, which reduces waste disposal. Safety is improved by installing dual flare systems in pressure relief headers; tandem pump seals; gas and fire detectors in all strategic areas; structural and equipment fireproofing; and proper firefighting training and equipment on site. Pollution is reduced by proper waste disposal efforts, more fuel-efficient operations, better emissions control, materials and inventory management, and dike containment systems around liquid storage tanks.[13]

Programmable logic controllers, developed in the automotive industry, have been used in the oil industry since the mid-1980's. PLC's were used initially for oil and gas extraction activities on offshore platforms to regulate separator fluids and to set fluid pressure levels. They are more reliable than the older regulating systems, and they reduce labor requirements. PLC's are now in use on some platforms to regulate nearly all processes associated with oil and gas production.

Offshore operations

Following the rise in oil prices in the 1970's, there was a rapid growth in offshore activity. Although drilling subsided during the last decade, large deposits of gas and oil in the Gulf of Mexico and elsewhere are supporting some additional oil platform operations. Most capital investment for offshore oil has moved to foreign shores, and worldwide offshore crude production has been stable at about 25 percent of total production during the past 10 years.

Due to the existing level of oil prices, companies are very concerned about risk. Rather than committing their resources to a full-scale development of offshore production, they are planning stage-by-stage development of offshore fields. The stages could include subsea completions, subsea manifolds, two-phase flow, extended reservoir testing, floating production, and offshore loading. This step-by-step development allows the companies to assess oil flow rates and other field characteristics before deciding to construct a production platform, pipeline, or both. (There have been significant developments in subsea completion techniques that have increased the accessibility of subsea reservoirs.) Development by stages also permits companies to determine optimal choices for platform types and pipeline layouts.

Platform development involves computer assisted design and imagining technology for engineering and assembly planning. Engineering work also benefits from document scanning. Blueprints and specifications are read by scanners into a data base. They can then be manipulated and merged with other computer files.

Newer platforms sometimes make use of submerged offshore loading systems. These systems use a base fixed to the sea floor and a system to carry crude oil from the platform through a transfer line to the tanker. Other platforms pipe oil to shore through pipeline configurations that are designed to minimize sea-current stress. A variety of methods to position pipelines in deep water are available, and most have been used in one form or another. Sometimes, the pipe is cushioned and protected by an artificial seaweed-like material. Computer programs used and modified as needed on site deal with problems related to installation stresses, optimal pipe configuration, bottom topography, residual installation tension, tow methods for bottom installation, and above-water installation methods when that option is considered. Significant equipment advances have been made in tension release mechanisms, seafloor frame and mattress pipe-support systems, anchoring systems, and bracketing systems.

New absorption caisson systems and stabilizing techniques protect platforms from severe weather, waves, and icebergs. New trailering and skidding technology reduces the need for cranes and other lifting systems.

The modular design of some platform segments eliminates the need for some main frame supports and some heavy-lift construction equipment. Using modular components can often lower the weight of a platform by thousands of tons, and make the transport and assembly of the components easier. Modular design also allows for more onshore assembly and faster platform fabrication. However, planning is very important. In some cases, an increase in the number of modules can complicate and delay hookups, cause construction lift capacity to decline, and increase steel requirements.

[13] Jeff Shepard, "Drill Pipe Management Extends Drillstring Life," *Oil and Gas Journal*, October 28, 1991, pp. 46-48.

Michael Morgan, "Production Site Safety and Environment," *Oil and Gas Journal*, October 28, 1991, pp. 44-46.

Advances and innovations in submersible pumping systems and special equipment for use in stormy or arctic climates opened up drilling and production possibilities in previously inaccessible areas. These advances raise the potential output for the future. However, new technology and equipment can only partly overcome the difficulty of drilling in the new areas. Potential new drilling areas in the United States usually require large work crews, and the labor requirements per barrel of oil extracted may be significantly higher than in existing fields.

In some areas, legal restrictions are forcing oil companies to cease dumping chemicals and waste materials into the sea. Virtually all waste from the oil platform must be barged to land for safer disposal. Although this had added significantly to the expense of platform operating costs, it has proven to be feasible. With further experience and more materials recycling, this process may become less expensive. By the end of the decade, all offshore operations may be required to stop dumping anything that could be viewed as harmful to the marine environment.

Although deep-sea, floating production technology is now feasible, the rate of development of deep-sea oil and gas fields is expected to be low in the 1990's. As a result, this technology may not be significant before the next century.

Computer aided design and drafting (CADD) has been in use since the late 1970's in two-dimensional, schematic form. Three-dimensional CADD for offshore structures was developed in the 1980's. Three-dimensional CADD will grow in importance because it shows more structural detail and is easier to interpret, but most of the present applications of this technology are in overseas locations.

Horizontal drilling

Oil production companies began experimenting with horizontal drilling in the 1970's, but, due to unforeseen problems, it took over a decade for the technology to be refined to the point that this approach was practical. This is a fairly common pattern in technological development. Once the proper solutions and applications are demonstrated, however, diffusion tends to be very rapid.[14]

In horizontal drilling, a well is drilled downward, and then the shaft is curved until it is virtually horizontal. The directional changes in the hole require special "mud motors" in the shaft and sophisticated directional monitoring and guidance equipment. Likely oil-bearing formations are entered from the side. This makes a greater number of relatively small and shallow pools of oil accessible and exploitable. The key to success in horizontal drilling depends on the potential flow and drainage patterns in the oil pool. Even some pools that were of a size to be commercially viable in vertical drilling have structural characteristics that have been shown to yield much more oil through horizontal drilling.

Most of the new equipment that allows for the directional changes in shaft angles is built into or lies just behind the drill bit. Compass-like, location gauges emit electrical signals that can be monitored from the surface. These signals allow the controllers to locate the precise position of the drill bit at all times. The control technology is part of "measurement-while-drilling," which has important applications in more conventional drilling as well as horizontal drilling.[15]

Directional precision contributes to the practicality of this technology. High output from tapped pools and precise drilling have lowered the drilling cost per barrel produced from $12 to $4 in several southern Texas oil fields. On the other hand, the higher potential for oil recovery has increased the prices of many oil leases up to 500 percent.[16]

This technology requires workers to learn new engineering, drilling, and mechanical skills. It alters the approaches to site analysis used by scientists and programmers. The boom in horizontal drilling has stimulated the demand for labor and increased capital investment.

Drill bit technology

Drill bits have used industrial diamonds for decades in oil and gas extraction. During the 1980's, polycrystalline-diamond-compact (PDC) bits were introduced and have been widely accepted. In this technology, the bit's cutter surface has a thin layer of polycrystalline diamond, a synthetic material, deposited on top of a strong tungsten-carbide substrate. The design is self-sharpening, which allows more rapid drilling at light bit loads than was previously possible. Faster drilling increases productivity and cuts labor demands and other drilling costs. PDC drill bits last longer, drill faster, and shear, rather than crush, rock. This results in more shaft stability and fewer well maintenance problems. These drill bits have no rolling components. They turn faster and they work well with downhole motors and high speed turbo drills.[17]

Drill bit lifetime, footage drilled per bit, and penetration speeds have improved steadily since the early 1980's. Cutter designs and drilling mud nozzle locations have been refined for better flow distribution below the bit. Drilling speeds of 750-1,500 feet per day can now be achieved over a broad range of conditions. Drills use a variety of improved materials, metals, and bearings. Newer high-speed drill bits use low-friction seals that reduce operating friction and temperature by 50 percent. The newer designs include flangeless lugs. These allow for more durable, longer roller bearings and bearing races that permit closer tolerances for high-speed applications. Partly due to the need

[14] M. G. Whitmire, "Fractured Zones Draw Horizontal Technology to Marietta Basin," *Oil and Gas Journal*, March 30, 1992, pp. 73-75.

[15] Trevor Burgess and Bernard Voisin, "Advances in MWD Technology Improve Real Time Data," *Oil and Gas Journal*, February 17, 1992, pp. 51-61.

[16] Thomas C. Hayes, "Horizontal Drilling, or How to Revive Oil Fields," *The New York Times*, July 14, 1990, p. 46.

Siegfried Schueler, "Horizontal Well Improves Recovery in Deep Sour Gas Field," *Oil and Gas Journal*, March 23, 1992, pp. 93-97.

[17] Roger Wollstadt, "Petroleum Industry Technology..."Discussion Paper #067, American Petroleum Institute, June 1991, p. 16.

Table 1. Major technological changes in oil and gas extraction

Technology	Description	Labor implications	Diffusion
Advances in the identification and imaging of potential oil and gas fields	The combination of accumulated exploration experience, advances in computer hardware, and software improvements has made it possible to more accurately identify potential sites for oil and gas drilling and to predict with a significant probability the size of deposits that may lie beneath the land or sea sites. The use of computer-aided oil exploration (CAEX) means that the number of "dry holes" drilled per successful discovery is declining. Explosives have given way to sonar analysis. Laser-based measurements and satellite and aerial photography data are also important inputs. Air guns in large arrays and multiple sensor arrays combine to yield data bases that can produce three-dimensional, color images of rock structures thousands of feet beneath the sea or land.	Although less exploratory drilling is conducted than in the past, the sites are often more difficult to develop. The lowered need for drilling causes the employment of oil field workers to decline. However, the greater difficulties in exploration that result from remote locations, offshore locations, and the increased average depth of potential oil fields tends to increase the need for labor. Moreover, to the extent that technology provides a higher success rate in drilling, the cost of producing oil and gas is lowered. This downward pressure on costs means that drilling can take place at lower anticipated market price levels than would otherwise be the case. This tends to improve the employment prospect of oil field workers when oil prices are relatively low.	The more challenging the potential exploration sites in terms of remoteness, field depth, and off-shore location, the more likely computerized imaging techniques and computer analyses will be used. At present, smaller oil companies are less likely to use the most recent techniques, since many are working in areas adjacent to established fields, and at relatively accessible depths. Yet, as costs drop and precision improves, virtually all exploration will use computerized imaging and analysis.Over 60 percent of seabed oil and gas exploration involved CAEX in 1991 and over 20 percent of land-based oil and gas exploration used CAEX.
Horizontal drilling	Horizontal drilling is responsible for most of the new drilling taking place in the United States. This technique starts conventionally by drilling downward, but the drill then follows a curved path and approaches potential oil bearing rock horizontally. This system has proven so effective that it allows for drilling in geological formations where drilling was considered uneconomical in the recent past. Slant drilling is a simpler variation on horizontal drilling that can be used in shallow fields with good results under the right conditions.	Horizontal drilling is a boon to oil field workers. Largely because of this technical advance, oil and gas field employment actually increased in 1990 after several years of decline. For these workers, there is no downside to this technology. Without horizontal drilling and slant drilling, employment would face an even more difficult future.	In some reservoirs, horizontal drilling has slashed the drilling cost per barrel of oil produced from $12 a barrel to $4. An advance this dramatic will diffuse as rapidly as new equipment can be produced and marketed, and new skills given to the drilling teams. The technique has spread throughout Texas in less than 3 years. It should be used nationwide within 5 years. During the coming 20 years, much of the additional oil that will be produced in the United States will come from enhanced recovery techniques and from drilling techniques that both improve the extraction of oil and lower the cost of bringing the oil out of the ground. Increasing the level of total oil recovery from each field allows mature fields to stay in production longer, and it raises the feasibility of developing new, smaller fields.
Refinements in established methods and equipment	Work methods and organization are undergoing steady improvements. Much of this is because oil and gas prices have been relatively low. This increases the pressure to organize work efficiently and to lower costs.	Although these changes lower the demand for labor, the associated lower costs also mean that drilling and production become feasible at lower market prices, which can increase employment opportunities.	Changes in work methods diffused rapidly in the mid and late 1980's. However, the diffusion of new equipment is quite slow. Older equipment is available at low prices, and many drilling and production organizations try to use their existing equipment stock for as long as feasible. It will be many years before this older equipment is discarded.

Table 1. Major technological changes in oil and gas extraction—Continued

Technology	Description	Labor implications	Diffusion
	Improvements in drilling hardware contributed to the development of horizontal drilling. Newer equipment—such as more powerful top drives—is easier to use, more durable, safer, and more economical over the life span of the part or material. Valves and safety cut-offs are more reliable and effective. Growing modularity in equipment design, easier methods of assembling and tearing down drilling sites, and better equipment accessibility for maintenance also have tended to lower operating costs. Safety measures, such as spill containment systems, fire detection sensors and extinguishing systems are improving the work environment. Waste management and recycling are being upgraded.	The changes in equipment also have tended to raise safety levels. However, the changes in work methods often expose temporary workers to greater danger. This is because temporary workers who come on-site only when needed tend to have less safety training than permanent workers. Their lower skill levels also increase their chances of having accidents.	
Enhanced oil recovery materials and techniques.	Oil producers have steadily improved their proportion of extraction of the oil and gas located at each production site. At first they used water, other drive fluids, steam, gas, and air to boost production from older wells. In recent years they have used chemical additives and inexpensive, free-flowing, but bulky, polymer–gels to boost production in fractured rock that tends to be bypassed by drive fluids. High energy gas injection also is being used to fracture rock and increase flow rates. Efforts to improve fracture stimulation technology have had significant success, which will help maintain production levels in the coming decade. Explosives have been used for decades to fracture rock and increase the flow of oil and gas. However, the past decade has witnessed improvements in explosive formulations and controls that have made this approach more precise and productive. Although not considered to be part of EOR, these advances affect how and where EOR techniques are used.	Oil recovery enhancement raises the demand for oil field workers. Higher skill levels and additional engineering work are usually needed to enhance recovery. These methods keep fields in production longer. In most cases, these fields produce oil for additional years or decades. In general, enhancement techniques do not expose workers to dangerous substances or other work hazards when conducted properly, nor do they lower the quality of the work environment. Fracture stimulation technology requires new skills in geoscience, explosives, and compressed gases.	The United States has aging oil fields in widely dispersed areas. Although these fields vary in geological settings, the enhanced recovery techniques spread quickly to any appropriate field. The extent to which enhanced recovery methods are used depends on oil prices. Some of the best systems can only be used at high price levels. At present, the National Petroleum Council estimates that at least a million barrels a day are added to U.S. production due to enhanced recovery. There are some very small, stripper fields located on family farms and private plots that are not benefiting from the newer methods and materials, but they account for less than 1 percent of the national oil and gas output.

Table 1. Major technological changes in oil and gas extraction—Continued

Technology	Description	Labor implications	Diffusion
Computer-based and related systems	This technology involves the use of computers for management information systems, office procedures, word processing, voice mail, facsimile transmission, accounting, data processing, record keeping, cross-referencing, billing, inventory control, and equipment and work-site monitoring. Computers also are used to manage and plan production levels, and programmable logic controllers manage many aspects of oil production.	The employment of clerical workers in accounting, billing, and records keeping is projected to remain flat or to decline. The employment of accountants, auditors, systems analysts, and computer programmers and operators is expected to grow substantially, but automation in accounting and auditing, as well as sharper than anticipated declines in domestic oil and gas activity, may alter this projection. Oil and gas industry professionals are learning computer skills and are using computers or computer output at a steadily increasing rate. At production sites, computer based systems and programmable logic controllers are raising productivity, lowering training requirements, and reducing the need for some kinds of production workers.	The costs of computing equipment and software have fallen enough to allow most of this industry to have in-house computer facilities for automated records and accounting data bases. Smaller companies may contract out for some of these services. Programmable logic controllers were adapted from automobile production to some offshore oil production functions and are now spreading to every aspect of offshore and onshore production.
Offshore drilling and production	Although improvements in steering and site location technologies have made free floating oil drilling feasible, it is still uncertain if the cost of drilling in deep ocean sites justifies any significant production from free-floating rigs in the near future. Eventually, free floating rigs may play a major role in offshore oil and gas production. The established oil platform technology will continue to be important on continental shelves. Platorms are being designed to better withstand severe storms and to prevent or extinguish platform fires. Platform assembly and transporting techniques have undergone some important improvements. Computer aided design and engineering are reducing the cost of designing and planning oil platforms. Piping and loading systems also have been improved.	Some refinements in assembly techniques and some changes in platform configuration may lower slightly the demand for labor. New equipment used on the platforms and improved drilling equipment may also reduce the demand for labor slightly. These changes improve safety and the work environment to which workers are subjected.	Oil platform production is limited and the capital requirements are quite large. Any significant improvements diffuse throughout the industry in under 5 years.

for high speeds, gas motors are giving way to electric, silicon-controlled rectifier, variable-speed drives. In the mid-1950's it took one drill bit to make 450 feet of hole. In 1987, one drill bit bored 3,340 feet of hole.[18]

Top drive systems, introduced in 1982, increase the amount of time the bit is actually rotating in the hole. Part of this improvement in rotation time is due to a 67-percent reduction in time needed to lay down, connect and remove drill hole pipe. The newer top drive, or overhead rotary systems, use 90-foot stands, as compared to the more common 30- and 60-foot stands. This reduces the number of connections and increases safety on the drill floor. The greater motive power makes insertion and removal of pipe sections safer. Reaming out variable-angled or bent pipe is easier with 90-foot stands than with single joints. And combined with more powerful top drives, the 90-foot stands increase the precision of directional drilling.[19]

Enhanced recovery methods

As oil flow rates drop in aging production fields, recovery rates can be sustained by artificial lift, and by injecting fluids, steam, or gases to build pressure and to push the crude oil out of the well. One of the oldest methods is simply to inject water. However, the limited porosity of the rock and the tendency of the water to create flow paths that bypass the oil can lessen the utility of water alone. Mechanical pumping, water pressure, and gas pressure (often natural gas injection) can raise the recovery rate to about 40 percent of the oil present in the rock.

Beyond the secondary recovery methods that use water or natural gas injection, there are tertiary recovery methods. These techniques constitute enhanced oil recovery (EOR), which can be complicated and relatively expensive. EOR can add years to the life of oil fields, but these methods are less likely to be initiated when oil prices are low. In EOR, steam, chemical surfactants, gases, and polymer-enhanced drive fluids are the most popular processes. Such techniques can often boost flow rates by adding pressure, preventing oil from escaping from the reservoir site through minute rock fractures, and altering oil viscosity to make it more fluid. Some polymer gels increase the oil flow through rock structures that are bypassed by other fluids. The cost is usually in the range of 25 cents to 2 dollars per additional barrel produced.[20]

Carbon dioxide flooding of production reservoirs in the United States increased from 17 projects in 1980 to 56 in 1990. This reflects the refinement and improved efficiency of CO2 enhanced oil recovery, which is projected to play an increasingly important role in the 1990's. In the latter year, there were 154 thermal projects and 50 chemical projects, down from 201 and 206, respectively, in 1986. Nitrogen can be used as an alternative to carbon dioxide, but it is usually less effective because it disperses unevenly in the oil.[21]

In 1986, EOR added 605,000 barrels a day to U.S. production. After declining to 500,000 barrels in 1989, the Middle East crisis triggered a spurt to 657,000 barrels per day in 1990. As prices declined after 1990, so did the number of enhanced production projects, but total EOR production in the United States was running an estimated 761,000 barrels per day in the first quarter of 1992.[22]

For several years, the industry has experimented with the use of microbes to aid in oil extraction by altering the viscosity of the oil and raising the gas pressure through microbial activity. Large scale use of this technology may not occur in the coming decade, but the concept has been shown to be sound, and the use of microbes may eventually be common. One potential problem is that this technology may be most appropriate for stripper wells, small production units where additional expenditures are difficult to justify.

Unconventional gas recovery is gradually coming into use. It is considered important for future natural gas production, and the techniques are relevant to some oil recovery. Although hydraulic pressure can be used to increase rock fracturing and oil or gas flow, greater precision and fewer collateral effects result from high-energy gas fracturing. Oil and gas frequently are found in sandstone formations. This commonly soft rock often can be extensively fractured by high-energy gas injection. This approach is cheaper than hydraulic fracturing, and it can be much more precise. Flow rates often double after this treatment.[23]

Most enhanced recovery techniques create demand for labor. They tend to raise the total cost of oil or gas per unit recovered, and can only be justified when oil and gas prices are expected to justify the higher costs. This raises the potential for future well development, given that fuel prices will eventually rise. Most enhanced recovery techniques require significant inputs of skilled, highly paid labor.

Explosives

Explosives have been used to fracture oil and gas bearing rock since the last century. Explosives generate shock waves at too fast a rate to do extensive fracturing. Slower rates of shock wave generation can spread much further at a level adequate to fracture rock. Newer solid propellants can achieve slower and more focussed explosive effects to a degree that was impossible in the recent past.[24]

[18] Roger Wollstadt, p. 17.

[19] Keith Rappold, "Development of More Powerful Top Drives Progresses, *Oil and Gas Journal*, February 17, 1992, pp. 61-66.

[20] Richard Sydansk and Philip Moore, "Gel Conformance Treatments Increase Oil Production in Wyoming," *Oil and Gas Journal*, January 22, 1992, pp. 40-44.

[21] Guntis Moritis, "EOR Increases 24% Worldwide; Claims 10% of U.S. Production," *Oil and Gas Journal Special*, April 20, 1992, pp. 51-79.

[22] Guntis Moritis, p. 57.

[23] Paul Druet and Sara O'Connor, "High Energy Gas Fracturing Succeeds in Central Lake Erie," *Oil and Gas Journal*, December 23, 1991, pp. 92-94.

[24] Paul Druet and Sara O'Connor, pp. 92-94.

The past decade has witnessed some dramatic improvements in fracture stimulation technology and in the understanding of fluid and gas flows in reservoirs. These advances require new skills in a variety of professions, and they alter the potential economic recovery levels of producing fields and potential oil and gas sites. Further improvements and skill changes are likely to occur in the coming 10 years.

The use of explosives in drilling and well completion has been refined to take advantage of growing precision in directing explosive forces. Current refinements also make better use of the growth in understanding of rock characteristics and fracture points. Although much less important than in the past, powerful explosives continue to play a role in exploration.

Computers

The present state of computer-aided exploration is based upon work stations and supercomputers. In the future, there will be a higher level of data and equipment integration than currently exists. Exploration service companies are in competition to increase their integrated services and to provide their clients with the latest technology.

As a result of the expanded science of geophysical exploration, the role of the geophysical contractor has changed. No longer a vendor of a set group of acquisition and processing services, the geophysical contractor has become the source of technical innovation for both equipment and techniques. This results partly from the decline in internal research and development within the large oil companies. Much of the crucial work involved in developing CAEX and in computer-aided design and engineering has come from service and instrument companies. This development might not have been possible without integrated computer workstations and improvements in computer networking.

The next stage of development will be to simultaneously reduce the cost of three-dimensional surveys while improving image resolution and data accuracy. Data management procedures will ensure the smooth flow of huge data volumes from acquisition to final product. Data management is aimed at removing from further evaluation most nonproductive areas, classifying and ranking the selected favorable targets, and indicating where seismic lines should be placed to be most effective. For both land and sea exploration, multisource and multicable signaling and sensor arrays will continue to grow in size and complexity.[25]

During the 1990's, an effective satellite-based global positioning system (GPS) will be established. This system should reduce oil and gas surveying time and improve survey reliability. Differential GPS techniques in combination with acoustical ranging devices should provide precision levels in the range of plus or minus 5 meters.

Universal scientific software will be developed that can run on supercomputers, mainframes, and workstations. (This software probably will be UNIX-based.) The problem will be to combine this flexibility with processing efficiency.

Data enhancement methods are crucial to the cost effectiveness of this new technology. Greater seismic detail can always be produced at a price. The companies that succeed in the 1990's will be the ones that can extract the most precision out of the least data, because they will be the ones giving clients the most value for their money.[26]

Computer software has been used in research for magnetic field analysis related to oil and gas exploration. Data produced by cesium vapor magnometers in drill holes and on airplanes can be analyzed to locate authigenic magnetic alterations in shallow sedimentary formations. Anomalous areas within these formations have high probabilities of oil and natural gas discovery.[27]

At production sites and in business offices, computer technology has tended to raise productivity. Personal computers are used widely for data base management, office activities, and general bookkeeping functions. At production sites, computers are used to measure the flow of natural gas and crude oil. Computer based flow management has successfully increased total production since 1980.

Integrated computer software used on workstations and personal computers provides gas and oil reserves estimates from past production profiles. This software can plot and project production declines and extraction cost changes. It can provide alternative production choices at differing price levels. This increases the producers' ability to alter production as market conditions change.

Heavy oil, related fuels, and oil alternatives

Because the price of oil has been relatively low in recent years, there has been little incentive to develop alternative fuels, or to exploit difficult-to-extract sources of oil. However, State and Federal legislation, including a Federal energy act signed into law in October 1992, require Federal, State, and private car and truck fleets to buy more vehicles that run on alternative fuels such as natural gas or electricity. The 1992 energy act provides tax breaks for purchasing alternative fuels. Moreover, the use of oxygenated fuels is mandated by the Clean Air Act Amendments of 1990 where air quality is often below required levels during the winter months.

Alternative energy sources include coal oil; alcohol fuels from biomass, natural gas, or coal; electricity; and hydrogen. The Federal Government and fossil fuel com-

[25] Elwood Nestvold and P. H. Nelson, "Explorers Still Hope to Improve on 3-D Seismic's Wealth of Data," *Oil and Gas Journal,* March 16, 1992, pp. 55-61.

[26] Mark Houston, "Trends: Contractors' Challenges, Abilities," *Oil and Gas Journal,* November 4, 1991, pp. 58-60.

[27] Robert S. Foote, "Exploration: Use of Magnetic Field Aids Oil Search," *Oil and Gas Journal,* May 4, 1992, pp. 137-142.

panies created demonstration projects for coal oil and gasoline, but the economics involved still do not justify any large-scale commercial development.

The main advantages of alcohol fuels are high octane and lower pollution levels for certain pollutants. In some areas of the country, ethyl alcohol (ethanol) produced from corn is being added to gasoline to reduce a few types of air pollution. Ethanol is also used in gasoline for tax advantage reasons and to raise octane. Ethanol contains just over 60 percent of the energy content of gasoline, so cars that have been adapted to use it get poorer mileage. Nevertheless, alcohol fuels in general raise the power performance of engines due to the evenness of combustion. Methanol has slightly more than 50 percent of gasoline's energy content and puts out high levels of aldehyde, some volatile vapors, and ozone, which are pollutants. Natural gas is the main source of methanol, but large scale production experiments have used coal as the principal sources of methanol. Methanol is cheaper to produce than ethanol, but both of these alcohol fuels and almost all other alternative fuels are more expensive to produce than gasoline. Newer, osmotic approaches to ethanol production may lower costs in the 1990's. During the coming decade, alcohol is unlikely to replace more than 10 percent of the gasoline market that would exist without alcohol alternatives. This is due to limited production potential and higher costs. Hybrid cars that can run on either ethanol or gasoline are common in Brazil. In Brazil, sugar cane is used to produce ethanol. Nevertheless, even that country's government has minimized its commitment to ethanol because gasoline is much cheaper. Unless the present abundance of gasoline were to end, it is unlikely that alcohol/gasoline hybrids will become more common in the United States in the foreseeable future.

Hydrogen can be produced from water, and one major oil company is producing high-purity hydrogen from refinery waste gas streams. It is a clean fuel, but it must be handled with great care. Germany is promoting hydrogen fuel development, but there is little interest in the United States at this time, which means that it is unlikely to affect the U.S. demand for oil and gas.

Compressed natural gas (CNG) is being used in over 40,000 corporate fleets, postal trucks, and gas utility vehicles. CNG is often cheaper to use than gasoline, but vehicle driving range is considerably less than that attained by similar vehicles using gasoline. Liquified natural gas has great potential, but it is expensive to handle due in part to the danger of explosion in vehicular crashes. Natural gas is unlikely to replace gasoline in private cars over the coming decade. However, natural gas has proven to be a practical fuel, and it produces little pollution. CNG will probably become a more important urban fuel in many areas of the United States during the coming 10 years. Also within 10 years, the public may be able to buy hybrid cars that run on either gasoline or natural gas. If gasoline powered vehicles are banned during high pollution periods, the owners of such vehicles may be able to continue running them by switching to natural gas. Low prices are restraining new gas development. Recent improvements in producing methane (basically, natural gas) from coal beds will not be widely exploited until prices rise significantly. There is, however, great potential to increase production if new markets are developed for natural gas.

The United States possesses large deposits of tar sand (heavy oil) and oil-bearing shale, but production is not significant. At a higher price for oil, perhaps $50 a barrel, it would be profitable to develop tar sand deposits, and heat-based enhanced recovery systems would become much more important in the industry. Oil shale also would become a more important source of petroleum products at this higher price, but not at the present price levels of around $20 a barrel. Technical progress has been made in lowering the cost of production for shale and tar oils, but there have been no dramatic breakthroughs.

One advance in heavy oil drilling involves the use of slant rigs, which require less measuring and special drill-hole lubrication equipment. Slant drilling follows a straight path, while horizontal drilling involves angling underground through the use of insite mud motors and measuring devices. Slant drilling is only feasible at shallow depths, but may be used eventually at depths of 17,000 feet below the surface.[28]

Although battery-powered cars still leave much to be desired, assembly line production of electric vehicles will begin in the United States during the late 1990's, and there are relatively good prospects for improved power cells for electric vehicles. Recent advances in fuel cell technology increase the likelihood that electrons in batteries eventually can be packed in the entire volume of a storage cell, rather than stored only on cell surface areas as is presently the case. This could bring about batteries that might provide hundreds of miles of travel without a recharge. Within 20 years, at least 5 percent of the motor vehicles sold each year may be electric, since other populous States and the Federal Government are expected to follow California's lead in requiring some zero-emissions vehicles.[29]

Any successful market expansion for coal oil, hydrogen, alcohol fuels, and electric vehicles could weaken oil prices and reduce the demand for labor in this industry. However, if natural gas were to become an important vehicle fuel, the demand for oil and gas workers would probably increase, because natural gas production development is presently depressed. It is unlikely, however, that natural gas-powered vehicles would proliferate rapidly enough to significantly reduce demand for domestically produced petroleum.

[28] Jeff Smith, "Slant Rigs Offer Big Payoffs in Shallow Drilling," *Oil and Gas Journal,* March 30, 1992, pp. 64-66.

[29] William K. Stevens, "Alternatives to Oil Move from the Lab to the Road," *The New York Times,* August 28, 1990, pp. C1 and C10.

Quality control and cost control systems

The economic conditions in the domestic petroleum industry feature growing environmental protection costs, regulatory costs, and depressed prices. The motivation to improve operations and control costs is intense. The industry has accepted the concept that quality and cost controls go hand-in-hand. Moreover, international protocols on operational and product quality, as well as industry models and informal standards, promote the adoption of new methods to insure the reliability of production processes.

Models and flow charts covering quality assurance systems and production processes have been refined and made less complex. These models are being applied to systems design and engineering, development, procurement and vendor monitoring, personnel and hiring, administrative systems, production, installation, plant and equipment, raw materials and supplies, servicing, security, pollution control, final inspection, testing, distribution and marketing, customer relations and information, and inventory control. All steps in these procedures are subjected to random audits and testing. Coordination involves the use of integrated computer data bases and management information systems.

The complexity and labor requirements of these systems have tended to limit them to larger, integrated companies, but new, less expensive software permits their use by smaller companies to improve quality and process control. Companies of various sizes can benefit from advances and software related to quality assurance engineering, statistical process control, quality control electronics, receiving control checks, in-process auditing, inspection equipment control, calibration standards control, flow calibration, nondestructive weld testing, product audit inspection, work place safety analysis, and fail-safe documenting procedures.[30]

When these systems are used effectively, they can reduce waste, improve quality, motivate employees, reduce overall costs, and raise productivity. An involved, analytical management team working within a framework of well-defined operational objectives is required to reap the benefits from quality and process control advances. Any system that adds more steps and labor input than it eliminates will tend to raise costs and reduce profits.

Capital Investment

Capital investment rose rapidly in the early 1980's but has declined since then. In 1992, the industry spent about $16.4 billion for new plant and equipment—less than one third of the outlays in 1981.

The rise in the price of oil in the 1979-80 period precipitated the investment level of the early 1980's. Private capital investment was $58.9 billion in 1981. Oil prices were so high in that year that capital investment was 27 percent of product shipment revenues. The decline from the near $59 billion capital investment level in 1981 and 1982 contributed to the economic problems in major oil producing States. As oil prices fell after 1982, capital investment fell as well. Capital investment levels were 13 percent of oil product shipment revenues in 1989.

The outlook for investment in the early 1990's is not encouraging since most oil and gas companies are planning further reductions in investment in the United States.[31] Many companies are investing in oversea areas where oil can be produced at a lower cost.

Although oil prices rose sharply in the second half of 1990, this price increase did not last long enough to encourage a significant resurgence in capital investment. Since then, no clear price pattern has emerged, and investment has declined. Private capital investment in oil and gas extraction was $19.6 billion in 1990, $18.7 billion in 1991, and $16.4 billion in 1992.[32]

The oil and gas extraction industry has adopted a more conservative investment strategy. The reasons for this change include the industry's experience in the 1980's with rapidly changing oil prices, less favorable and unfavorable tax policies, and restrictions on exploration or production in wilderness and some offshore areas. The industry carefully evaluates changes in price and supply levels before making new expenditures. In the present environment, technological change must be clearly cost effective in order to attract significant capital investment.

Research and development

Although low oil and gas prices are depressing research and development efforts in oil and gas extraction, over a billion dollars are spent each year to improve exploration technologies, and many billions are devoted to leasing and exploration activities. However, expenditures on exploration wells have plummeted since their peak in 1982 when $42.7 billion was spent on these activities. In 1991, just $8.5 billion was spent on exploration wells, and 1992 expenditures appear to have been weak as the total number of wells drilled (both dry and productive) declined to an estimated 22,000 from 29,440 drilled in 1991.[33] There is usually a 5- to 10-year lag between exploration and large-scale production. Thus, the continuing decline in domestic exploration means that it is unlikely that any significant increases in oil production will occur in the United States before the next century. Past experience in domestic oil production has shown that large increases in oil field investments yield very modest output increases in the short run. Production has begun to decline on the North Slope of Alaska, and few other U.S. fields hold significant potential for rapid production boosts in response to price increases.

[30] Fred Vermeer, "ISO Certification Pays Off in Quality Improvement," *Oil and Gas Journal*, April 13, 1992, pp. 47-52.

[31] Mark Potts, "Mobil Plans to Cut Capital Spending, *The Washington Post*, March 19, 1992, pp. D10, D13.

[32] U.S. Department of Commerce, Bureau of Economic Analysis data.

[33] *U.S. Industrial Outlook* 1993, p. 3-5, and information supplied by the U.S. Department of Commerce, Bureau of Economic Analysis.

Output and Productivity

Output

Production of crude petroleum from U.S. fields has been slowly declining. Between 1973 and 1991, the BLS combined index for crude petroleum and natural gas production fell at an average annual rate of 1.1 percent a year, despite the fact that natural gas production has been rising in recent years.[34] During this period, combined production only increased in 1977, 1978, 1984, and 1991. (See chart 1.)

During 1973-79, the downward trend was 1.4 percent annually, and, more recently, during 1979-91, production trended down an average 1.0 percent each year. Domestic crude oil production has fallen to an estimated 7.2 million barrels a day in 1992, and petroleum imports have risen to close to 50 percent of consumption.

Oil drilling activity in 1992 declined to the lowest level since World War II. Fewer than 700 rotary drilling rigs were in use during the year. Off-shore activity also was low.[35] This depressed rate of activity reflects the expectation that oil prices will not rise significantly in the near future.

When the price of oil is depressed over a period of years, many marginal wells are taken out of production. Most of these wells fall into the stripper well category, which means they produce less than barrels of oil per day. In 1986, nearly 3 out of 4 U.S. producing wells were stripper wells, and they accounted for 14.5 percent of crude oil production. By 1990, the average daily production of a stripper well fell to 2.3 barrels, and many of these small wells are being shut down.[36]

Due to growth in the consumption of fuels other than oil and gas, and the acceleration of energy conservation measures, natural gas and petroleum products accounted for less than 65 percent of U.S. energy consumption in 1990, compared to 77 percent in 1973.[37]

Productivity

Productivity in crude petroleum and natural gas production (SIC 1311), as measured by the BLS index of output per employee hour, has not fared well over the past two decades.[38] Over the 1973-91 period, output per employee hour declined an average of 3.1 percent a year with the sharpest declines in productivity occurring before 1983. Between 1973 and 1979, productivity declined at a high average annual rate of 7.3 percent; however, during 1979-91, output per employee hour decreased by an average of 1.0 percent annually, sharply slowing the previous pattern of substantial decline. Productivity rose each year from 1984 to 1988. The 1984 rise reflects higher output, but the other annual productivity increases, which include a 9.1-percent rise in 1986 and a 9.8-percent rise in 1987, mainly reflect lower employment in almost all occupational groups, the abandonment of marginal stripper well production, and successful enhanced oil recovery activity which tended to be less labor-intensive than most of the marginal operations that were shut down.

Crude oil production has declined steadily over the 1973-91 period. Estimates for 1992, when a daily average of 7.2 million barrels of crude oil were produced, indicate that the rate of decline which persisted during the latter half of this period is continuing. As crude oil production has declined, natural gas production has risen, with an estimated 18.5 trillion cubic feet produced in 1992. A further decline in crude oil production and an increase in natural gas production is forecast for 1993.[39] Average output per producing well has been declining slowly since 1972, which has had a negative effect on productivity. The declining output is the result of aging oil fields.

Employee hours associated with oil and gas production have been volatile during the 1973-91 period. The result is that there was little relationship between production and hours worked. As hours worked increased, production did not go up significantly; as hours worked declined, production remained fairly stable. Some of the decline in hours worked in recent years was due to cut-backs and the lengthening of intervals between maintenance and changeover activities. (See chart 1.)

Employee-hours, the labor component in the BLS productivity measure, increased an average of 2.1 percent a year from 1973 to 1991. During 1973-79, employee-hours rose 6.3 percent a year. Over the period 1979-91, however, employee-hours increased sharply and then declined slowly to yield no change for the period. From 1973 to 1982, the average increase in employee-hours was 8.0 percent annually. From 1982 to 1991, employee-hours decreased at an annual rate of 3.5 percent.

Employment and Occupational Trends

Employment

The number of employees in the oil and gas industry varied significantly during the 1973 to 1992 period. Although employment increased at an annual rate of 1.3 percent over this period, the rate of growth during 1973-79 was substantially higher, 9.6 percent; during 1979-92, however, employment declined at an annual rate of 2.3 percent.[40]

[34] Changes in output and productivity are measured by the compound rate formula. The output and productivity data discussed in this section are from BLS Bulletin 2421, *Productivity Measures for Selected Industries and Government Services, April 1993*

[35] *U.S. Industrial Outlook 1993*, p. 3-4.

[36] *Basic Petroleum Data Book, American Petroleum Institute*, May 1990, section IV, table 3.

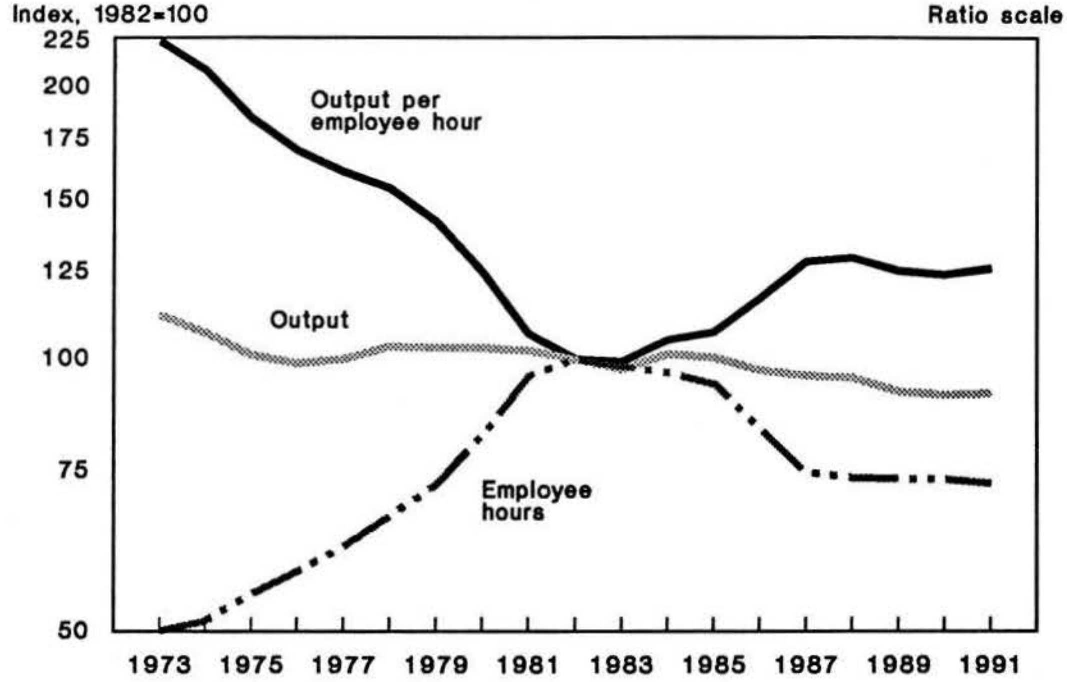
[37] *Annual Energy Review, 1990*, Department of Energy, May 1991, p. 7.

[38] As of 1993, BLS has a productivity measure for crude petroleum and natural gas production (SIC 1311). A measure for oil and gas drilling is under development.

[39] *U.S. Industrial Outlook 1993*, p. 3-4.

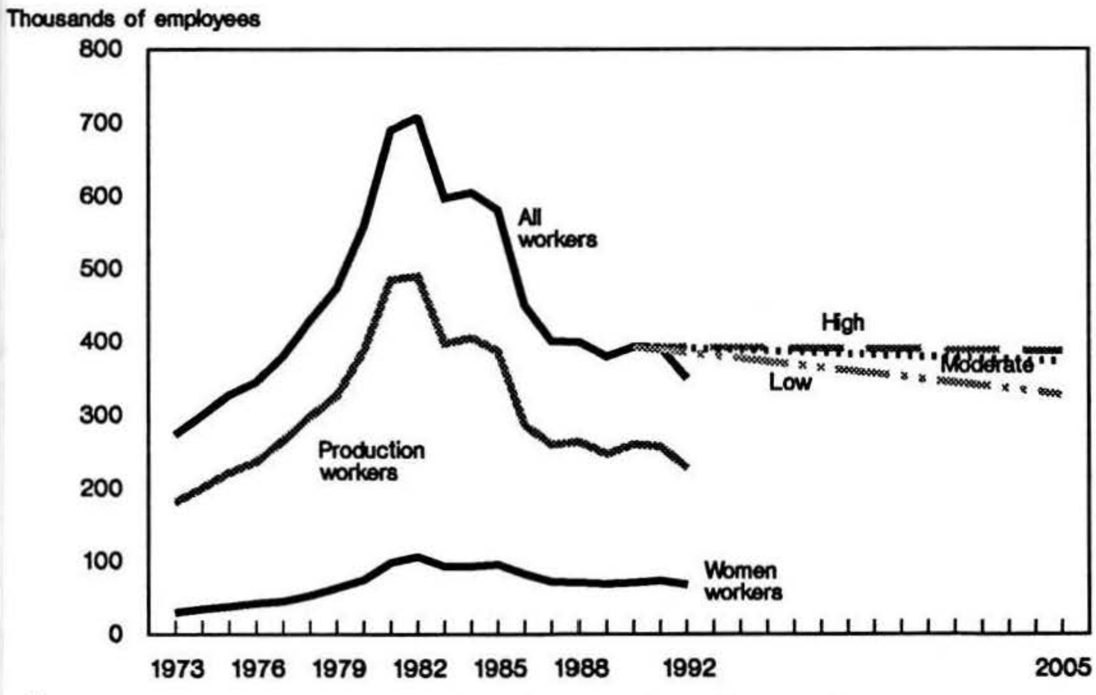
[40] Average annual percent change for employment are based on data published by BLS in *Employment, Hours, and Earnings* and are calculated by the compound rate formula.

Chart 1. Output per employee hour and related data, crude petroleum and natural gas production (SIC 1311), 1973-91[1]



[1]Productivity data for the rest of SIC 13 was not available.
Source: Bureau of Labor Statistics

Chart 2. Employment in oil and gas extraction (SIC 13), 1973-92, and projections,[1] 1990-2005



[1]Projections are based upon high, moderate, or low economic growth assumptions.
Source: Bureau of Labor Statistics

An examination of employment data by year provides further insight into the severity of the contraction of employment in the oil and gas industry. (See chart 2.) From a level of 273,900 workers in 1973, employment peaked at 708,300 in 1982. After declining during most of the 1980's, employment averaged 350,300 in 1992. Most employment in oil and gas extraction is divided between crude petroleum and natural gas extraction (SIC 131, 132) and oil and gas field services (SIC 138). Less than 2 percent of current employment falls outside these SIC divisions. Crude petroleum and natural gas employed 180,700 workers in 1992, down from 192,000 in 1991. Oil and gas field services employed 163,700 workers, a 16-percent decrease from the 195,700 employed in 1991.

The decline in employment after the early 1980's in the oil and gas extraction industry resulted from high production levels abroad. Abundant supplies held down oil prices and led to a fall-off in exploration and drilling activity.

The pattern of employment change for production workers was similar to the trend for all employees. Between 1973 and 1992, production worker employment rose an average of 1.1 percent a year. From 1973 to 1979, the rise averaged 10.3 percent a year. During 1979-92, employment of this group of workers declined an average of 2.8 percent a year. Production worker employment peaked during 1982, and declined from 1982 to 1992, when 226,100 workers were employed in oil and gas production.

The patterns of production worker employment were very different in the two major segments of the industry. Crude oil and gas extraction employed 91,800 production workers in 1992, 40.6 percent of production employment in SIC 13. The same year, oil and gas field services employed 130,000 production workers, or 57.5 percent of production employment. Oil and gas field service production employment declined over 17 percent from 1991 to 1992, but the employment decrease in the crude oil and gas sector was a less severe 5.9 percent.

Women employees in oil and gas extraction have grown from 31,100 in 1973 to 69,600 in 1992. The peak year of employment was 1982, when 107,000 women were working in oil and gas extraction. During 1973-92, employment rose an average of 4.3 percent yearly. During the 1973-79 period, the increase averaged 12.8 percent each year. Between 1979 and 1992, the employment of women in oil and gas extraction rose 0.7 percent each year. The crude petroleum and natural gas extraction sector of the industry employed 49,500 women in 1992, which amounted to 27.4 percent of the sector's employment. Oil and gas field services employed 19,200 women in 1992, 11.7 percent of employment.

The BLS projection for employment change in oil and gas extraction (moderate version) is for a drop from 394,700 in 1990 to 377,100 in 2005, an average annual decline of 0.3 percent.[41] In crude petroleum and natural gas, employment is projected to fall at an annual average rate of 0.7 percent from 191,900 to 172,300. In contrast, the number of oil and gas field services workers is projected to rise 0.2 percent a year from 198,300 in 1990 to 204,800 in 2005. This partly reflects anticipated labor demand to shut down production from marginal wells.

Table 2. Employment trends in oil and gas extraction, 1973-92 and projection, 1990-2005

Period	Average annual rate of change: All employees	Average annual rate of change: Production workers
1973-92	1.3	1.1
1973-79	9.6	10.3
1979-92	-2.3	-2.8
1990-2005 projection (moderate)[2]	-0.3	

[1] Compound rate formula used to calculate percent changes.

[2] See text footnote 41.

Source: Bureau of Labor Statistics.

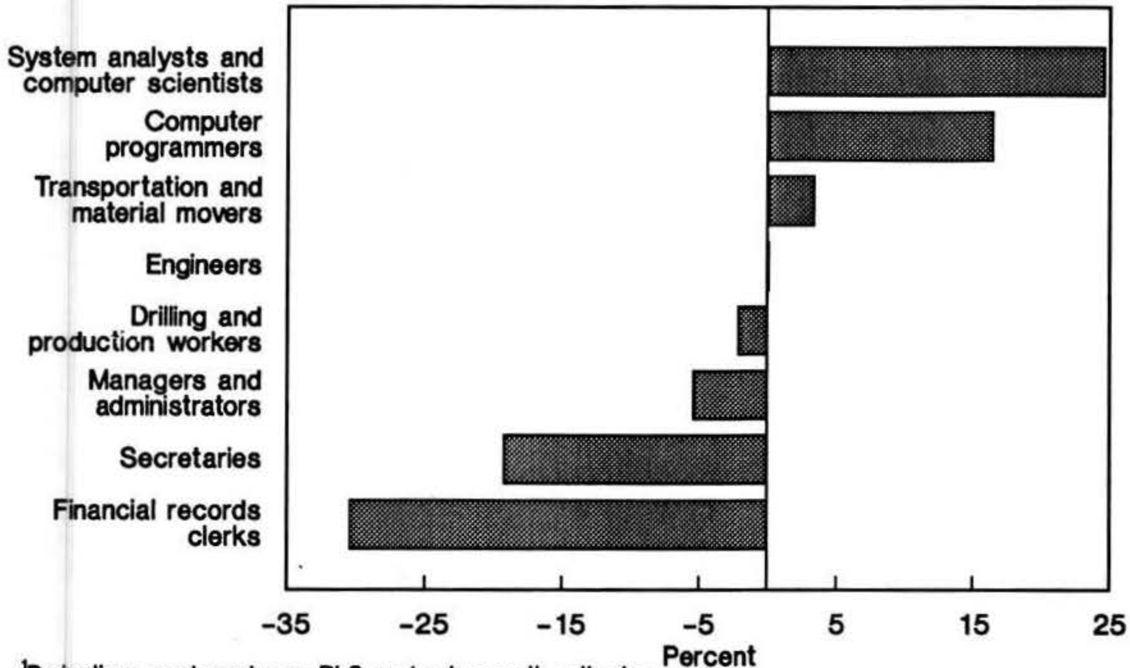
Occupations

There is a higher proportion of nonproduction workers in oil and gas extraction than in most other mining industries. Drilling and exploration work generally is performed under contract by the oil and gas field services industry, SIC 138. Slightly more than half of all workers in oil and gas extraction are engineers, computer specialists, mathematicians, scientists, administrative personnel, lawyers, clerical personnel, and other nonproduction workers. Production workers include roustabouts, hoist operators, mechanics, pumpers, painters, welders, truck drivers, and well-service personnel. The occupational employment information that follows applies to all of SIC 13, which includes oil and gas extraction, as well as oil and gas services.

Most occupational groups will experience stability or small declines in employment according to BLS projections. The number of managers and administrators (38,000 in 1990) is expected to decline 5.4 percent between 1990 and 2005. The moderate growth projection is for just under 36,000 of these workers in 2005. Management support occupations are projected to decline from 21,475 in 1990 to 21,150 in 2005, a fall of 1.5 percent. However, within the management support category, the number of personnel, training, and labor relations specialists is expected to increase 4.6 percent, from about 1,620 in 1990 to close to 1,700 in 2005. Activities involving these occupations are expected to grow in importance. (See chart 3.)

[41] BLS assumptions for employment projections are based upon high, moderate, and low levels of economic growth. In this industry, there is little difference in projected 2005 employment under the assumptions of high or moderate growth.

Chart 3. Projected changes in employment in oil and gas extraction (SIC 13) by selected occupations, 1990-2005[1]



[1]Projections are based upon BLS moderate growth estimates.
Source: Bureau of Labor Statistics

No significant change in the total number of engineers is projected for 2005. There were 20,935 engineers of all sorts working in oil and gas extraction in 1990. The number of petroleum engineers, the dominant group in this industry, is projected to decline 1.4 percent, from just over 13,950 in 1990 to about 13,750 in 2005. This reflects the belief that there will be no major growth in exploration and drilling. It also takes into consideration the lower proportion of dry wells that may be drilled due to new technology. BLS does not collect data under the heading "geoscientist." There were 15,474 geologists, geophysicists, and oceanographers employed by businesses classified as being within SIC 13. The projection is for no change in employment to 2005 for these combined occupations. However, the actual outlook is very difficult to project. Geoscience employment could fall substantially within this SIC, as it apparently had during the early 1990's. A significant number of geoscience positions may be created in small businesses that contract to do work or research in oil and gas related activities but which are not classified in SIC 13. This is discussed in more detail in the next paragraph. In contrast, the number of computer, mathematical, and operations research analysts is projected to grow about 25 percent over through 2005. There were about 3,075 of these professionals in 1990, and more than 3,830 are anticipated to be working in 2005. Nearly 90 percent of these professionals are systems analysts and computer scientists, so BLS expects more computerization and more systems control of operations.

There is a significant shift underway in the domestic oil industry as to where some of the scientific, mathematical, and computer-related work is located. Major oil companies are selling many of the assets and older oil fields that are located in the United States. In many cases, small, technology-based independents have either acquired some of these fields or have gone into business to manage or consult on their use. In other cases, these small companies have concentrated on exploration and production in areas that were bypassed or overlooked by larger companies. Often, a core management-technology group of two to five people attempts to use technology in innovative ways to manage relatively large oil fields and to extract value from them that the major companies have discounted or ignored. In order to increase productivity and flexibility, they contract for specific services to conduct operations. While employment opportunities for geoscientists and engineers have been declining in the major oil companies, new opportunities are emerging in the new, smaller groups. Without these changes the projected employment outlook for highly educated and skilled professionals would be bleak, and without these new groups the outlook for oil and gas production would probably be worse than it is.

The number of technicians and related support workers is projected to decline 3.3 percent, from over 17,430 in 1990 to about 16,850 in 2005. Among engineering and science technicians and technologists, the decline is projected to be 7.0 percent. There were nearly 14,100 of these workers in 1990, and the projection is for fewer than 13,120 in 2005. The employment of computer programmers in oil and gas extraction is projected to grow over 17 percent, from about 2,560 in 1990 to nearly 3,000 in 2005, which is roughly in line with the projected growth in systems analysts and computer scientists.

Due partly to increased automation, the number of administrative support workers is projected to decrease by 18.8 percent, from nearly 59,500 in 1990 to about 48,300 in 2005. The number of clerical workers in financial records processing is projected to fall from 13,080 in 1990 to 9,100 in 2005, or by 30 percent. The further diffusion of computers and accounting software explains most of this projected change.

There were slightly more than 19,200 secretaries, stenographers, and typists working in the industry in 1990, and this group is expected to decline by about 21 percent to less than 15,200 in 2005, as computer word processing, voice mail, and other developing office technologies are introduced more extensively. Employment of general office clerks is projected to decline by about 6 percent over this period.

Precision production, craft, and repair occupations are of major importance in oil and gas extraction, and they account for over a third of employment in the industry. There were 141,500 workers in these occupations in 1990. The projection is for about to 137,000 to be working in 2005, a decline of just over 3 percent. The number of blue-collar worker supervisors is projected to fall nearly 7 percent by 2005.

There were about 86,460 extractive and related workers, including blasters, working in 1990. Their number is expected to decline by 2.3 percent to 84,480 in 2005. Within this category the most important group is roustabouts. These workers do most of the oil drilling labor. There were nearly 37,700 of them working in 1990, and the projection is for about 36,320 in 2005. This decline of nearly 10 percent mainly reflects the negative outlook for an increase in oil drilling activity.

In spite of the expected decline in drilling activity, the number of mechanics, installers, and repairers is not expected to change significantly. In part, this is because of the aging of many producing oil fields, which tends to raise maintenance needs. There were 16,785 of these workers in 1990, and the projection is for 16,650 in 2005, a change of less than 1 percent.

The employment of operators, fabricators, and laborers also is projected to remain flat from 1990 to 2005. There were about 60,360 of these workers in 1990, and the projection is for approximately 60,930 in 2005, a change of close to 1 percent. Most of these workers are involved in transportation and material moving. The number of truck drivers is projected to increase by nearly 10 percent to about 13,780 in 2005. The increased maintenance associated with aging oil fields require transporting repair parts and materials to sustain oil production. The number of material moving equipment operators is projected to be stable to 2005.

Adjusting to Technological Change

The oil and gas extraction industry has closely monitored developments in technology and has been quick to introduce the latest innovations for exploration, drilling, and extraction of oil and gas. The industry workforce is accustomed to change, and the requirement to adopt new skills and undertake related adjustments associated with these developments.

The biggest unions in the industry are the Oil, Chemical and Atomic Workers (OCAW) and the International Brotherhood of Teamsters. However, much of the industry is not unionized, and a significant amount of production occurs in areas where union strength is relatively low and where there are right-to-work laws. There has been a trend toward using more intermittent workers, but the importance of skill and experience in this industry could limit this trend. The work force tends to be more mobile than in most industries, and their work schedules are more flexible.

Dramatic declines in employment in recent years and the expectation that employment will not grow between the present and 2005 are forcing many workers out of this industry and limiting opportunities for new workers. The employees who remain tend to be highly skilled and experienced. Since opportunities for entry into oil and gas extraction occupations are limited, much of the training of new workers will remain on an informal basis. As noted previously, programmable logic controllers are reducing some field training requirements, and they are reducing the demand for some production workers. Nevertheless, the anticipated growth of nearly 5 percent in the number of personnel, training, and labor relations specialists, while overall employment is expected to fall, reflects the growing importance of these activities in oil and gas extraction.

An important labor-management agreement was signed in 1990. Although only 4,500 workers at several facilities were subject to the agreement, it served as a model for another 300 to 350 industry contracts, especially those that cover nearly 40,000 OCAW members in oil and gas extraction.[42]

The contract provided for wages to rise about 5 percent a year over 3 years. Since 1973, average hourly wages in this industry have risen from $4.33 to $12.94 in current dollars. This is roughly in line with inflation, but does not represent an increase in real wages. The 1990 contract continued to keep workers at least even with inflation. Oil and gas field services workers did not do as well as crude petroleum and natural gas company employees. During

[42] AMOCO-Oil, Chemical and Atomic Workers Comprehensive Agreement, February 1990.

1973-90, the former group of workers had wage increases of 273 percent, as their hourly wages rose on average from \$4.06 to \$11.10. Crude petroleum and natural gas workers had wage increases of 339 percent, as their wages rose from \$4.78 to \$16.22 per hour.[43]

Increases in company contributions to health insurance costs also were designed to keep these benefits from being eroded by inflation. The contract included a \$250,000 death benefit for survivors of an employee killed on the job. It also included company paid training of transportation and marketing employees who must take the Department of Transportation's driving license tests. The contract also provided up to 26 weeks at full pay for an absence due to occupational illness or injury, and another 26 weeks at half pay.[44]

[43] *Employment, Hours, and Earnings, 1909-90,* and July 1991 Supplement, Bureau of Labor Statistics.

[44] Michael H. Cimini, "Developments in Industrial Relations," *Monthly Labor Review,* April 1990, p. 42.

Although the union and the company failed to agree on environmental monitoring, this issue likely will be addressed in the next series of contracts. Hazardous wastes are a major issue in this industry, as are noise and air pollution. Moreover, workers can be exposed to high radiation levels from radium brought out of the ground with the crude oil. The problem is most severe in the South, but radiation is present in virtually all oil fields.[45]

Safety issues remain a major concern in the industry, and companies and unions will continue to monitor hazards, training, and safety programs. The unions also are expected to try to arrest the shifting of work from crude oil and gas production establishments to less unionized, contract oil and gas service companies, and to limit the use of intermittent workers. In the face of declining employment, issues related to seniority, training, and job security also are expected to be important.

[45] "Radiation Danger Found in Oil Fields Across the Nation," *The New York Times,* December 3, 1990, pp. A1 and B6.

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Chapter 2. Commercial Banking

Important technological changes are taking place within the commercial banking industry (SIC 602).[1] Computer-related technologies play a vital role in banking. During the past decade, check processing productivity increased rapidly as the automated equipment that "reads" the magnetic ink on checks improved. Check clearing automation has been crucially important for banks and clearing houses to process the large and growing number of check transactions. Similarly, high-speed sorting and counting equipment has improved.

Banking has become very dependent on computers. Computer networking has grown rapidly in banking operations. Automated management information systems, fund transfer systems, a powerful type of computer database system called "relational," and automated auditing systems also have become common. Unlike ordinary databases, relational databases can automatically merge and adjust information from any number of separate, related tables, as long as they contain a field in common, such as an ID number. This can significantly lower the amount of time it takes to carry out common banking procedures.

Many changes are occurring in the industry as a result of revisions in interstate banking practices. Large-scale consolidations have increased the importance of bigger banks in mid-sized urban areas. Several cities, including Charlotte and Pittsburgh, are emerging as rivals to New York, Boston, Chicago, San Francisco, and Los Angeles as major banking centers, while other major urban areas have seen a decline in the relative market importance of their local banks. The widespread failures among savings and loan institutions have diminished their importance in banking. Some healthy savings and loans have converted to State chartered and federally chartered banks, while many savings and loan institutions have gone out of business or been merged into other institutions.

Insolvencies and profit problems in banking have stimulated a drive to reduce employment and boost productivity. The industry is experiencing substantial consolidation, and cost control measures have been strengthened, but these changes are just beginning to produce significant savings and productivity benefits.[2] A BLS study of bank staffing patterns between 1987 and 1990 showed no significant change in staffing patterns from the recent past.[3] The authors concluded that the expected dramatic changes would occur in the coming years. More recent data support this conclusion.

Technology, laws and regulations, and business patterns continue to evolve as banking markets shift, and banks strive to redefine their areas of operations. The rapid pace of technological change in computers and office automation, combined with changes in legal and economic situations, have made it difficult to develop any agreed-upon idea as to what constitutes "size-efficiency." In fact, it may well be impossible to define some optimal size efficiency for commercial banking because technological changes, shifts in targeted customers, and changes in market composition are forcing operational changes. Moreover, scale economies differ with the type of banking, the forms and mix of revenue, and the geographic region of operation. Marketing areas have tended to expand, and a large and growing number of bank customers, such as mail-order houses, are national in scope. Many banks are stressing fee-generated income more than in the past, which can alter scale-economies.

Software developers have sought to restrict how banks and other companies use and adapt their products. This could limit software economies and inhibit reducing the royalty or software purchase cost per use.[4]

Social and economic changes have removed some working class people from the customer base of commercial banks. For example, check cashing services have grown rapidly in inner-city areas to serve this population. These highly profitable services may evolve into a new, although limited, form of banking.

Corporations outside of the banking industry have begun to provide many bank services including a wide variety of loans, credit cards, and money market accounts with checking privileges. Both large and medium size companies have become adept at raising capital without the assistance of commercial banks. These changes have motivated banks to create or find new products to market and to seek more fee-based income.

Output of commercial banks, as measured by the Bureau of Labor Statistics composite transaction index of deposits, loans, and trust services, increased by an average

[1] Standard Industrial Classification 602 includes commercial banks, which are chartered by the Federal Government, a State, or some other government entity.

[2] Michael McNamee, Zachary Schiller, and Geoffrey Smith, "Are Fewer Banks Better?" *Business Week*, August 17, 1992, pp. 92-93.

[3] Jeffrey C. Kuster, "Occupational Employment in Commercial Banking," 1987-90, *Monthly Labor Review*, April 1993, pp. 21-25.

[4] Staff Reporter, "Computer Associates Is Suing First Fidelity Over Use of Software," *The Wall Street Journal*, May 6, 1992, p. B4.

annual rate of 3.8 percent between 1973 and 1990, the latest data available. The year-to-year changes were uneven, but output declined in 3 years of this period, 1974, 1980, and 1989. Output rose an average of 4.6 percent a year between 1973 and 1979. During the 1979-90 period, output increased an average of 3.4 percent yearly.

Productivity in commercial banking (output per hour of all persons) increased at an average annual rate of 1.6 percent during 1973-90. The pattern of productivity growth was different from the growth pattern of output. Although productivity grew only 0.6 percent per year in the 1973-79 period, the rate of productivity growth more than tripled to 2.2 percent yearly in the 1979-90 period.

Commercial banks are a major source of jobs in the service sector, with 1.5 million employed in the industry in 1992. Between 1973 and 1992, employment increased at an average annual rate of 1.8 percent. Between 1973 and 1979, the number of commercial banking workers rose 4.0 percent annually. During the more recent 1979-92 period, employment growth slowed to a rate of 0.8 percent per year. The rate of employment growth in commercial banks, savings institutions, and credit unions is projected by BLS to be less than 1 percent annually during the coming decade.[5]

The structure of employment has changed as automated equipment has replaced some clerical workers and tellers. The share of nonsupervisory workers in total employment fell from 80 percent in 1973 to 71 percent in 1992. Women have been an important part of the banking labor force for many decades, and the proportion of women employed in commercial banking is increasing. In 1973, 66 percent of workers were women. In 1992, the proportion of women employed in commercial banking was substantially higher, 75 percent.

BLS projections of employment for commercial banking are not available separately but are included in the broader industry grouping of commercial banks, savings institutions, and credit unions. However, commercial banks are a significant proportion of this group, comprising 73 percent of total employment in 1990. These financial institutions had combined employment of 2,134,600 in 1990. The moderate projection for employment in 2005 is 2,324,900, an average annual increase of 0.6 percent. Some experts foresee greater productivity growth. As banks merge and expand into new business areas, such as insurance and investments, there may be less redundancy, and greater economies of scale.

Within occupations, the rate of growth is projected to be highest for computer, mathematical, and operations research analysts. Employment in these occupations may expand by 3.0 percent a year from 24,150 in 1990 to nearly 37,600 in 2005. Bank tellers are the largest group of workers included in the projections and employment in this category is expected to decline 0.4 percent a year, from 505,000 in 1990 to under 477,000 in 2005. This projected decline reflects the elimination of duplicate operations, further automation of bank teller functions, and the closing of some bank offices as institutions merge and consolidate.

Some commercial banks make extensive use of formal training programs. The use of contractors who provide both off-site and on-site training is widespread. Programmed training has become an accepted practice. Training is geared to both new employees and workers who need new skills because of changing technology and job content. On-the-job training remains very common, especially in small banks and branch operations.

Industry Structure

The commercial banking industry is made up of thousands of banks and branches. At the end of 1992, there were 3,591 federally chartered banks, 7,870 State chartered banks, and 414 savings banks, a total of 11,875. Including the branch offices, the total number of banking offices exceeded 65,000 at the end of 1992. About 75 percent of all bank assets were held by the largest 600 institutions during 1989, but industry consolidation advanced so rapidly that about 78 percent of total industry assets were held by the 300 largest banks in 1992. These 300 banks held $2.8 trillion of the $3.6 trillion total.[6] Time deposits and certificates were declining as a share of total assets. These accounts decreased from an average of $1.09 trillion in 1990 to $860 billion in 1992. About 300 foreign banks from over 50 countries operated 747 bank offices in the U.S. at the beginning of 1992, but these foreign bank offices are in SIC 608 and are not included in any of the financial, employment, output, and productivity data in this report.[7] In 1991, commercial banks held over $3.6 trillion in assets and had about $2.4 trillion in loans outstanding. They held over $2.4 trillion in deposits and about $670 billion in investments.[8]

Commercial banks are just one form of financial institution. Investment banks and non-banks, such as savings and loan institutions, insurance companies, brokerage houses, and mutual fund groups, have entered business areas that once were dominated by commercial banks. Many of these institutions offer money market accounts that allow demand drafts (checks) to be written against them. As interest rates on savings have dropped, non-banks have attracted personal savings into their money market accounts, and low-risk mutual investments. Some large

[5] BLS makes employment projections based upon assumptions about high, moderate, or low levels of economic growth. The assumption used for rates and numbers in the text is for moderate economic growth between 1990 and 2005.

[6] Wanda Cantrell, "Banking Makes a Comeback, *Bank Management*, May 1993, pp. 34-40, and FDIC supplied data.

[7] *Statistical Abstract of the United States 1991*, p. 499. *U.S. Industrial Outlook 1993*, p. 45-2, and FDIC data.

[8] *U.S. Industrial Outlook 1992*, p. 46-1.

non-banking corporations have entered the credit card business, and many non-banks make loans. Commercial banks now account for less than one third of financial assets, and their share is declining. This trend has affected employment levels and is expected to continue to be a factor in the future.

In 1990, commercial banks cleared 45.4 billion checks and handled over 1.5 billion electronic fund transfer transactions through ATM's. In the same year, commercial banks processed more than 1.2 billion deposit transactions and 749.2 million withdrawal transactions. During 1990, these banks made over 1.5 million home mortgage loans and more than 17,000 business mortgage loans. They made 22.7 million consumer installment loans and processed 3.6 billion credit card transactions including over 135 million cash advances. The number of commercial and farm loan transactions was 934,800. Banks supervised 1.5 million trust department discretionary accounts.[9]

The McFadden Act of 1927 and an amendment to the Bank Holding Company Act of 1956 prohibit almost all interstate branch banking. The Glass-Steagall Act, passed by Congress in the 1930's, separates commercial banking from most direct involvement in business activities other than lending and most investment banking involving stocks, bonds, and underwriting. Commercial banks are restricted to debt instrument investments, some trust and fiduciary activities, acquiring deposits, and the making and servicing of loans.

Some banks made sizable loans to borrowers that got into financial difficulties during the 1980's. These involved bad real estate loans and loans to companies that have since failed or encountered severe cash flow problems. Some restrictions on bank holding companies have been relaxed in order to allow them to reduce operating costs and seek to increase profits by expanding operations, merging with other banks, and entering new markets. Many States have allowed more out-of-State entry into their banking markets. The Federal Government has permitted many mergers and expanded operations, but the Government increased the level of regulation and requirements that pertain to reserves and solvency.

During 1991 and 1992, commercial banks increased the spread between their cost of funds and their interest income from lending and debt instrument activities. This has improved total commercial banking profits to record levels. The Federal Deposit Insurance Corporation reported that its member banks earned $15.5 billion in profits during the first half of the 1992.[10] Still, hundreds of banks remain in significant financial difficulty, and 60 banks failed in the first half of 1992. The FDIC, however, has substantially reduced its estimates of the number of banks that are likely to fail in the 1990's. The banks defined as "problem banks" by the Federal Deposit Insurance Corporation (FDIC) held a total of $609 billion in assets in mid-1992. Despite record profits, banks are behaving cautiously due to the continuing financial problems facing this industry and the increase in regulatory financial oversight.[11]

After December 19, 1992, Federal legislation required the Government to take control of "functionally" insolvent banks. It is expected that fewer than 100 banks will be taken over during 1993. Although some banks may fail, the direct costs of insurance liabilities will be covered by deposit insurance premiums paid by banks. These premiums were increased and restructured in recent years due to the higher levels of insolvency during the 1980's. The dramatically improved profitability of many banks in 1992 and 1993 has reduced the scope of this problem.

Technology in the 1990's

Computerization has had profound effects on banking operations. Telecommunications have tended to centralize administration and some decision making, but the improvement in communication has also empowered some workers at the branch bank level and off-site workers, and increased their ability to make decisions. Interbank operations have benefited from electronic fund transfers, better sorting and processing systems, and improved computer links. A variety of optical and imaging technologies have improved data entry systems and altered document verification systems, although the potential future uses for optical imaging and optical character recognition remain largely untapped. Refinements in accounting and evaluation methods are causing major changes in financial institutions. The recent successes in developing more precise evaluation procedures have begun to alter the cost structure of banking, and these techniques reduce the amount of equipment and labor needed to bring a customer account on line. Equipment and computer software continue to improve. Because of problems in the 1980's, risk assessment systems are becoming more computerized and complex. Risk management pertains to many areas. For example, increased automation entails risks that a general system crash could compromise or abort thousands of transactions. High level of concern over the volatility of future interest rates has made designing loan risk management systems more difficult, but future risk-management developments will depend on the business environment. A long-term period of economic growth with low inflation and steady, low interest rates could reshape the priorities of risk management. A summary of major innovations in commercial banking is presented in table 3.

In terms of diffusion, the automation of transaction processing is most advanced. The automation of management

[9] Data provided by the American Bankers Association and the Federal Reserve System.

[10] Jerry Knight, "Bank Deposit Insurance Rate Hike Reviewed," *The Washington Post*, September 15, 1992, pp. D1 and D4.

[11] Jerry Knight, "Rate Cuts Push Bank Profits Up," *The Washington Post*, September 10, 1992, pp. D11, D14; and Jerry Knight, "FDIC Slashes Estimate of 1993 Bank Failures," *The Washington Post*, March 24, 1993, p. F3.

information systems is advancing rapidly. Remote banking through private telephones, phone instruments specifically designed for banking and other financial transactions, home and office personal computers, and other remote banking devices will spread during the 1990's. Before the end of the decade, automated expert banking systems and automated lower-level decision making may be more widely used.

Computerization of bank functions

A wide assortment of data processing and electronic funds transfer operations are based on computer technology and software. Only government operations make use of more computers than financial service industries. Within financial services, commercial banks are exceptionally intense users of computer technology. Number processing and data sorting are central to banking operations. Since the end of the 1970's, distributive data processing has diffused to all large and intermediate sized banking operations in the United States. Computers are the best tools available for many banking operations.[12]

On-line operations. In the 1980's, there was a shift away from large-scale, mainframe-based batch processing of computer data to less bundled modes or item processing for some banking operations. Most medium to large commercial banks continue to perform much of their check capture, account posting, and customer statement generation in a centralized, batch mode. Some auditing procedures, data verification, and backup operations are still done through batch processing, but other activities are often handled on a distributed basis. Batch processing means that data entry is a discrete operation and that all data processing jobs are entered into computer memory during a single operation. On-line means that the computer can receive data for different tasks at anytime, which often leads to more flexible and less centralized computer-related work scheduling.

As more tasks are done on line, programming can monitor and gather data for subsequent off-line, distributed, or cooperative processing. Just as changing one number in a spread sheet can automatically change the numbers in other spread sheet cells, on-line operations can now alter other data that is affected by the operation underway. Because computer speeds have risen, customers and bank workers can obtain needed information in a very short time, often in seconds. They can also generate statements and reports through on-line, automated processes.

Open systems. Open computer systems allow systems designers to provide greater flexibility and more interactive functions than proprietary systems. However, this sometimes causes users to contend with more complexity. Users often are required to learn more and be extremely careful in using the system. As the computer markets at all levels—mainframes, minicomputers, work stations, and personal computers—have become more competitive, vendors have been compelled to offer programs and hardware that can interact with data, text, and graphics from dissimilar systems. These open systems can often work harmoniously with other systems, although the technology of task sharing between dissimilar computers, operating systems, and programs is still in its infancy.

Fault-tolerant systems. On-line operations, especially operations involving customers (mainly through ATM's and modems used for home and office banking) and inexperienced bank employees, need to be able to withstand the data entry mistakes the users may make. Fault-tolerance is the ability of hardware and software to recover from a problem without the intervention of an operator and without the loss or distortion on data. The problems could be in hardware, power supply, or data input. (In the recent past, serious errors by users could erase data or cause system operations to go down.) Moreover, these systems often need to coach users through the proper steps and help them to correct or recover from mistakes they may make.

Greater fault tolerance is being designed into all types of computer systems. For example, minicomputer manufacturers are defending their market shares by making their machines, operating systems, fund transfers, and programs both more user friendly and fault tolerant. Less skilled employees have become involved in computer operations, and customers can perform more transactions directly with automated equipment.

Multitalented (multifaceted) workstations. Workstations are basically super-PC's. The hardware is more substantial than a desk-top PC, but it can still fit in an employee's work area. These machines have capabilities to do tasks that previously have required a mini-computer or mainframe, and they can be used to process large batches of data downloaded from mini and mainframe computers. Workstations were originally used for scientific research and higher mathematical procedures, but they are being used for other complex tasks that are less numbers oriented. For example, newer workstations are more flexible and can be used in automated office operations, such as customer file maintenance. They also can be used in risk assessment and data base analysis, such as customer targeting.

Stand-alone workstations are still common, but the trend is toward networks of workstations in medium-size and large commercial banks. Some workstations contain integrated voice-data terminals that can respond in person or by telephone voice. Voice response units have provided impressive improvements in productivity. This means that data can be entered through the spoken voice or through the keys of a touch tone telephone. Workstations are posing a serious market challenge to minicomputers, just as

[12] Olivier Bertrand and Thierry Noyelle, *Technological Change in Banks and Insurance Companies*, Centre for Educational Research and Innovation, Organisation for Economic Co-operation and Development, 1988, p. 21.

minicomputers did to mainframes in the early 1980's. Workstations sometimes require different and fewer operations support workers and simpler maintenance tasks than mainframe and minicomputer systems.

One key to the power of workstations is reduced instruction set computing (RISC). Core integrated circuits (IC's) used in these computers are designed specifically for the tasks that they will normally perform, rather than designed for a variety of tasks that include many that might be performed rarely. This is called "designing-to-use," and it increases processing speeds for the more common tasks performed by these IC's.

Multitalented workstations require separate, linked integrated circuits for their central processing systems. Each IC in designed to handle a specific type of operation. The IC's in these computers can handle scientific, algebraic, database, graphic, voice, and facsimile tasks. They are used in automated data back-up, storage and retrieval, and as controllers for ATM operations. These workstations can be used in open, more flexible systems.

Multiuser systems/networks. Computer networks based upon mainframe computers, minicomputers, and personal computers linked through server units have been expanding in importance in commercial banking. This allows equipment, such as printers and large-scale data storage devices, to be shared by the network users. More importantly, data bases can be shared and data downloading capabilities expanded. Networks also allow more monitoring of work processes and general activity.

These systems have undergone significant improvements. Network problems occur less frequently and are solved more rapidly than in the past. Redundant systems and backup provisions function more smoothly. Operating speeds continue to increase, and queuing/priority systems have become more sophisticated.

In the future, networks may make better use of the idle computing power in personal computers that are tied into the systems. The computing and processing capabilities of personal computers can only be used at a relatively low level in most networks. The open systems technology mentioned previously and new task-division, parallel processing technology should play important roles in raising the power of network computing. Any success along these lines could lower further the need for mainframe computers and minicomputers. Such success might also aid in increasing automation in branch and remote-office operations.

Mainframe computer partitioning. The competition from minicomputers, workstations, and personal computers has seriously reduced the potential markets for mainframe computers. This is due partly to the large investment of money and personnel that is needed to operate mainframe facilities. Over time, the computing costs per data-unit-processed on mainframe systems has steadily declined, but alternative systems often offer more economy and flexibility. New methods of controlling mainframe operating systems can allow the central processing unit (CPU) to be partitioned into the equivalent of from two to eight separate computers. This allows a more complete use of CPU time, and it further lowers the effective cost of mainframe computer operations.

Having a mainframe computer operate like a system of separate, powerful computers increases the potential markets for these expensive machines, and commercial banking is one of the most important markets. This technology also may help in the development of more open, flexible systems, as discussed in a previous section. As a spin-off from designing partitioned systems, some user access procedures have been simplified. Making systems access more user-friendly can lower the demand for computer operators because the difficulties of linking systems and operations tend to be reduced.

Telecommunications

Although computers are a driving force in banking technology, advances in telecommunications also have played a vital role in the development of modern banking operations. Through computer networks and telephone line links, branches and remote banking offices are tied into the central processing and administrative centers of the larger commercial banks.

In general, the autonomy of branch and off-site operations has steadily diminished over the past decade, and control has been centralized. There are, however, exceptions to this trend, and some branch and off-site staff have been allowed to make more decisions involving loans and payment terms without approval from the central office. Automatic teller machines and money dispensing machines are tied to a central operations office. The newest ATM's have high-resolution graphics, easy-to-read symbols, instructions in Braille, voice guidance systems, and wheelchair access. Some of these innovations have been influenced by the 1992 Americans with Disabilities Act. To enter details and transaction amounts, users may tap the screen. Video icons and beeps signal the completion of each step. Some new ATM's incorporate enhanced magnetic ink character recognition line readers and image processing technology. These machines can accept and process many checks.[13] Banks are addressing the need for greater security for their customers using ATM's. Some machines have been relocated inside the bank building, and video cameras monitor the machine areas. Simple additions to ATM capabilities, such as providing coinage means that fewer transactions require dealing with a teller inside the bank. Some branch operations now require fewer personnel. As enhanced ATM's come on line during the mid-1990's, even fewer tellers will be needed in branch operations. Clerical work has been centralized and automated, and those clerical tasks remaining in the branches

[13] "ATMS for ADA," *Time*, Oct. 12, 1992, p. 29.

are usually performed by tellers. Loan operations are conducted from fewer offices, and transactions are reviewed more rapidly by management using computerized evaluation procedures.

Due to a variety of factors, such as central control, activity integrity, privacy, the structure of telephone charges, deficiencies in non-urban phone systems, and the slow pace of local telephone companies in instituting totally digital transmission systems (relative to the long-line companies), some larger banks have created proprietary communication-line systems that include both voice and data communication between offices. These systems are extremely expensive and require skilled labor to install, maintain, and operate, and many banks rely on outside suppliers.

At least one State telephone regulatory agency has proposed a rate structure that will make a local telephone company-run digital telecommunications system available at reasonable cost. If this works as planned, the rate of diffusion could be very rapid, and major commercial operations in many industries, including commercial banking, could be linked by high-speed, wide-band digital communications and computer networks by the end of the century. The rate of data transmission would be at least 10 times the present rate, and banking could become even more centralized. Such systems could allow ATM's to provide two-way video communication. Many services only available on a person-to-person basis may undergo further automation, and customer services may experience significant productivity growth, which could ease demand growth for customer service representatives. This development could also increase the centralization of these functions and broaden the job content of these workers.

Fax machines, Fax cards, and Fax modems have played a minor role in banking transactions, but that is changing. Using Fax for communication has been shown to speed up loan processing and raise productivity. Fax based systems for a variety of bank transactions have been developed and are undergoing refinements. The potential utility of Fax machines in banking may turn out to be very significant.[14]

Banks, telephones companies, and other businesses have introduced telephone based services for bill paying, banking, and conducting other financial transactions. These services use specially designed telephone instruments to carry out the assigned tasks. Consumers pay a monthly rate for the service. The instruments are either sold separately or bundled into the monthly rate. It is not yet clear how successful these services will be. One small problem is that they must compete with similar services available to the minority of consumers who own personal computers and modems. So, these services are often designed for customers who are less interested in becoming involved in technology processes.

Television-based banking services similar to those just described may become significant during the 1990's. A microwave/cable system is being offered in several large urban areas, and a two-way cable service will be tested in Florida beginning in 1993.

Interbank operations

Interbank fund transfers are an essential part of the banking system, and computers have contributed to the efficient handling of these transactions. Every day, any given bank loses deposits as customers write checks which are deposited in other banks, but gains deposits from checks written on other financial institutions and deposited in its accounts. Debit card transactions and credit card payments add significantly to these transfers. On a typical business day, commercial banks process over 80 million checks drawn on other banks, and they conduct more than 10 million other interbank transfers.

There has been steady progress in facilitating the transfer of funds between banks. The Federal Reserve Banks play a major role in this process by debiting and crediting the accounts that banks in their regions maintain at the Reserve Bank. Banks reduce clearing fees by sending presorted checks to the Federal Reserve Bank in their region. Most banks have short-cut arrangements for many of their most frequent transactions. An example of this is a clearing house operation serving correspondent banks. Since two or more banks share local, frequent, or strategic transactions, they establish a clearing system to debit and credit each other's accounts. Unless the transactions are quite limited, these systems are computerized. Clearing house operations continue to be automated and are becoming more national in scope. Banks, of course, sort and retain for internal debiting and crediting the checks passing between accounts in their own bank.

As in a modern computer spreadsheet, the debiting of one bank's reserve account can automatically credit another bank and deposit relevant information in other parts of the system. These systems also can sort and total data. When not presorted, coded check entries could be made in a random pattern and subjected to a data base sort for some cooperative or internal clearing, but institutions must still do a physical sort to return checks to customers or to retain checks as paper transactions records.

Both the government and private sectors benefit from the rapidly growing level of automation in clearing house transactions. Much of the interbank transfers are done electronically, as discussed in a following section. Because banks expect check processing volume to continue growing despite the good prospects for debit card growth, the industry is looking for ways to convert the check from a paper item to an electronic one at the earliest point of entry into the financial system. For example, some of the newest ATM's can convert a hand written check into an electronic document.

[14] "Lowly Fax Leads Banks to New Mortgage Markets," *Bank Technology News*, January 1993, pp. 1 & 12-14.

In the past, processing bank checks was among the most labor intensive major functions in the banking system. Changes in the process of initial check entry by tellers and other processors has modestly increased productivity and reduced error rates. The expanded mandatory use of magnetic inks on checks has allowed more automated processing of some of the uniform check data, such as banks, branches, and account numbers. Magnetic ink character recognition equipment is becoming even more accurate, and processing speeds increased sharply in the 1980's. Most of the machine data entry during processing is done by "reading" magnetic ink. This further reduces the manual steps during processing. Productivity growth in interbank transfers has held the demand for clearing operations clerical workers fairly stable, despite a rapid increase in the number of these transactions.

Optical scanning devices in tandem with optical character recognition programming can now "read" hand written information on checks with 50 percent accuracy. This may lead to major technological change and processing labor savings in the next few years. Future productivity increases will probably come in part from optical technologies. A human operator can verify the machine reading on a video screen and only key in data when the machine has erred. Fifty percent accuracy by a machine reading of the check value will cut in half the number of needed key strokes to enter values.

Commercially-issued checks, a very important portion of the total, will mainly be encoded and printed with magnetic inks that will allow more automated processing in the near future. When clearing operations receive mixed bundles of personal and commercial checks, new sorting equipment can separate the checks into coherent groups. This also has contributed to productivity growth in check clearing.

Electronic fund transfers

Electronic transfer of funds (EFT) has permitted much more automation of key banking operations than would otherwise be the case. Banks and clearing operations are adopting new technology at a rapid pace, as they expand their levels of EFT. In addition to the use of EFT for check entry, and for debit and credit card transactions, the expansion of automated, electronic clearing operations, fund transfers, and interbank payments has become extremely important to the entire system. National organizations and businesses have grown rapidly to meet the needs of these financial transfer markets. Examples of these include the Fedwire System, Clearinghouse-Interbank Payments System (CHIPS), and the Automated Clearing House (ACH).

Optical and imaging technologies

Biometric scanning. Biometric technology is one of several imaging innovations becoming important in banking. Biometrics include such things as hand sizes and shapes, fingerprints, and retinal patterns. Automated signature verification is not literally biometric, but makes use of the same type of technology. As a result, the clerical work related to these forms of verification is becoming more efficient. Research is underway to use biometrics to increase security and reduce fraud in ATM, credit card, and debit card transactions.

Card transactions throughout the economy are mainly signature based—as are credit cards—or they are verified by the use of a personal identification number (PIN), as are debit cards and telephone calling cards. Both signature and PIN systems are vulnerable to abuse. For instance, credit card transactions by telephone are especially vulnerable to fraud. A biometric approach might categorize voices by a variety of characteristics and assign numeric codes to certain pronunciations, tones/timbres, inflections, and breathing patterns. A device attached to the phone of an operator/sales representative would verify the voice code, which would be supplied along with the credit card number verification.

Similar technologies, while not biometric in nature, may make advanced currency verification and automated counterfeiting monitors available within a few years.

Image scanning and digitized image scanning. "Reading" documents into a database or word processing program, or "reading" charts and other images can reduce the need for data entry clerks. As scanning equipment accuracy has grown and prices have fallen, image and character recognition technology to convert images to digital data has developed. Most hand-written data, however, cannot yet be "read" with adequate accuracy. This technology involves optical scanners, a variety of mass storage devices, automated data-backup systems, and image interpreters/digitizers.

High resolution video terminals, color printers, laser printers, plotters, and other image output devices also are important. Even without the expected improvements in digitizing accuracy, increased, efficient use of document scanning, digital image conversion, display devices, storage systems, and output devices should produce significant productivity increases during the 1990's.

Optical disk storage. Optical (or laser) disks have advanced from a read-only format to a read-and-write format. These disks can hold huge quantities of data in a non-volatile manner. This means that magnetic problems and other interference will not erase information. These systems provide improved data access, paper savings, staff reductions, higher data integrity, and lower costs per unit of data stored and processed.

Table 3. Major technological changes in commercial banking

Technology	Description	Labor implications	Diffusion
Computerization	Banks are among the most computerized businesses. Recent technology changes include improvements and innovations in on-line operations, open systems, fault-tolerant minicomputers, multitalented workstations, multiuser systems, and mainframe computer partitioning. Future developments may include intelligent networks that better use personal computers and linked workstations. Computer systems are becoming easier to use and more resistant to accepting data entry errors. Computerization has made it practical for banks to create new mortgage products, such as reverse equity mortgages, shared equity mortgages, and a variety of adjustable rate mortgages. New consumer loan products and equity loan products have also entered banking markets, and new commercial loan products are expected to grow in importance.	Some of these developments increase the demand for systems experts and some programmers. Due to shared peripheral equipment in multiuser systems and open system architecture, the total amount of computer hardware needed for banking tasks may be reduced, which means less demand for computer hardware maintenance and repair personnel. The simplification of procedures and higher speeds of processing reduce labor requirements for bank tellers, secretaries, and clerical workers. Increasing the variety of banking products tends to increase the demand for customer service representatives and related loan officers. Bank tellers have become more involved in direct marketing of bank products to consumers. Some management opportunities are created to oversee the development and marketing of new types of loans and new debit card operations. Computer controlled voice response units have reduced the demand for low-level customer service representatives and operators.	Some modern technology is useful only in very large banking and bank service operations with established mainframe computer centers. However, many recent computer technology innovations and improvements are applicable to all levels of banking, and some of the initial costs can be recouped within a short period. Less expensive technologies of this sort diffuse nationwide within 2 or 3 years. For the expensive, new systems, the rate of diffusion is hard to predict. Banks have become more cautious than in the past about investing in new, complex systems. The unknown potential and costs of competing minicomputer systems and workstation networks also makes it difficult to predict the future need for mainframe systems and computer partitioning. Many new products made feasible by computerization are designed to lower the banks' risks in making loans. Such products tend to diffuse rapidly. Products needed to maintain or expand market share also spread rapidly.
Telecommunications	The integration of advanced telecommunication systems with the computer networks in banking operations has allowed some activities to be centralized, yet it has allowed other activities to be offered at new sites, such as supermarkets. There have been major advances in Automatic teller machines and telephone-based banking services.	Telecommunications have eliminated entire branch operations and some jobs in bank branches are disappearing. These systems have made automatic teller machines even more useful than they were in the past because the telephone line network linkage systems operate more rapidly and reliably.	Diffusion of telecommunication systems is slowed by cost and by the need to maintain a human presence in some market areas. Banks can lose business when there are no longer convenient branches where customers can talk face-to-face with bank service representatives. The leveling off and modest decline in ATM sales at the end of the 1980's stimulated the development of more versatile ATM equipment. Sales have strengthened, and the rate of diffusion of these new machines should increase. The telephone companies' delay in switching to all-digital systems and line problems in less populated areas adversely affects the growth of banking telecommunications. Competition among telephone companies and the potential for proprietary telecommunication systems to become cheaper and more user-friendly should increase the rate and economy of banking telecommunication advances and diffusion by the late 1990's. Because they affect the

Table 3. Major technological changes in commercial banking—Continued

Technology	Description	Labor implications	Diffusion
			customer cost basis of telecommunications through rate setting, State telephone regulatory agencies may play a role in this transition.
Interbank operations	Improvements in computers and software have made the Federal Reserve clearing centers, and the intra-branch and inter-bank transaction clearing operations more efficient and automated.	Automation and simplification/verification of data entry processes has outpaced the growth in bank transactions. The result is a reduced need for clerical workers in clearing operations, but managers and more skilled professionals continue to experience modest job growth.	The Federal Reserve system has adopted new technology and methods. The rapidity of diffusion to other clearing operations depends on the scope and size of these operations, because the costs of conversion can be steep. Some smaller clearinghouses have been merged into larger scale operations to take advantage of new technology.
Optical data entry, data storage, and related systems	The improvement and price declines in optical scanners and related technology are allowing banks to eliminate some of their manual data entry systems. Optical disk data storage allows banks to store both new and old data quickly and economically. Biometric scanning is used to verify signatures, fingerprints, and other traits that can uniquely identify an individual. Related, optical systems for currency verification are being developed.	Optical entry and storage systems reduce paperwork and the need for clerks and computer keying. These system have no effect on the demand for management, customer service representative, professional staff, and other highly skilled staff. If biometric scanning becomes common, demand for tellers and some related clerical staff will decline. Less staff training related to these forms of identity verification may be required by banks. Automated currency verification would have similar implications.	The rate of diffusion has been slowed by the problems associated with older scanners and by the cost of optical scanning and data storage. Diffusion is proceeding at a rapid rate among large banks, and optical data entry and storage may be common in smaller banks by the late 1990's. If the cost of biometric scanning continues to decline and reliability proves to be good, these devices will be in general use by the end of the century. Newer copying and computerized printing technology has increased the threat of counterfeiting. Reliable currency verification systems may diffuse rapidly.
Accounting technologies and integrated information systems	Accounting for transactions and evaluating bank performance is now incorporated in relational databases that have evolved from the process technology of distributive data processing. Advanced telecommunications tie branch and remote office data into the central systems as the transactions are recorded. Auditing through the computer became routine during the 1980's. The availability of interactive, modular software, management information systems, relational databases, expert systems, and related software technology has made information about all aspects of bank operations, balance sheets, and accounts easily available to bank management and financial professionals.	Accounting is more centralized than in the past. Automation means fewer accounting clerks, but the demand for CPA's and high-level accountants and auditors continues to grow in spite of automation, centralization, and bank mergers. The major reason for this is the growth in the number of bank products. Integrated information systems tend to centralize management. Demand for branch staff professionals and managers declines. Some layers of management can be eliminated because so much information and measuring criteria have become available without intermediaries. However, the growth in the volume of data and information to be processed also can create work for programmers, systems analysts, technical librarians, and other information specialists. Rule-based expert systems and artificial intelligence systems will continue to improve work accuracy and reduce fraud loss.	The diffusion of new techniques and software is very rapid. The major constraint is the time necessary to evaluate the cost-benefits of new methods, equipment, and software, and the recruiting or training of staff. Diffusion of integrated information systems has been very rapid among larger banks. Most intermediate sized banks will probably move into advanced, integrated information systems during the coming 10 years. Many small banks do not need the full capabilities of these systems.

Table 3. Major technological changes in commercial banking—Continued

Technology	Description	Labor implications	Diffusion
Other office automation	Banks are benefitting from the same new office systems found in other important businesses. These automated, computerized systems handle filing, ordering goods and services, inventory control, tracking and overseeing maintenance and repair functions, monitoring and controlling office and building environmental control systems, word processing, mail systems, and payroll/personnel management.	Office automation has been slow to produce labor savings, but there is a growing trend in that direction. The 1990's are expected to experience more rapid productivity growth related to office automation because adjustments in work patterns that were needed to benefit from the changes in office technology are now well underway. Branch office personnel demands at all levels may decline, and there may be some reduction in central office clerical and secretarial staffs.	Because of stricter oversight of procurement costs, the rate of office automation growth in the 1990's may slow from the rate experienced in the 1980's. Banks will not abandon useful older equipment without a very clear idea of significant benefits from buying or leasing newer systems.
Credit card and debit card operations	The knowledge and technology gained from credit card operations has been extended into debit card operations. A debit card can credit and debit accounts on a near-instantaneous basis through the use of automatic teller machines and point-of-sale terminals linked directly to the banking system or a linked intermediary. Magnetic strips on the cards are "read" by these machines. The central data bases authorize and record transactions. "Smart cards" that use integrated circuitry in place of, or in addition to, magnetic strips may replace the present cards before the end of the century.	Processing credit card slips remains relatively labor intensive, although some credit card fund transfers are largely electronic in nature. In contrast, debit card operations are among the most automated in the banking industry. These cards are becoming more useful and widely applied as electronic fund transfer technology advances. As this technology grows, fewer clerical workers and bank tellers may be needed. Because "smart cards" are more versatile than the present cards, labor requirements will decline even more if these cards come into general use.	Credit cards will continue to be widely used. The more widespread use of debit cards may be one of the most important changes in the economic patterns in the 1990's. By the end of the decade, debit cards may be used in many situations presently involving checks or cash. Bankers hope to eventually replace most check transactions with debit card transactions. The cost-benefits of "smart cards" appear very favorable. These cards are capable of multiple functions and a single card could serve as a health card, calling card, credit and debit card, driver's license, and virtually any other use a card could serve. However, the reluctance to merge all these functions and the capital invested in magnetic stripe equipment should slow the acceptance of "smart cards."

Integrated information systems and accounting technologies

Data analysis, accounting, and auditing systems are structured and formatted to accommodate advanced computer technologies to search for, match, and process vast quantities of data. These are tasks that benefit from a distributed data processing environment. The steady advance in data processing since World War II has had and continues to have a major effect on economic and social life and the structure of financial labor markets. These new distributive data processing systems are an important step toward reducing paper work. Recent progress in distributed data processing systems design contributed to further automation of transaction processing, automation of management reporting, the development of management information systems, and new telecommunications links and automated computer-based links between banks, branches, and customers. During the 1990's, advances in computer-based expert systems should allow greater automation and integration of all of these processes.

Integrated information systems. Computer-based management information systems have evolved to the point that most relevant information can be provided to key personnel at their computer consoles. One potential consequence of integrated information systems is that management may assume more control and delegate less. Decision making at the branch level on loans and operations is becoming less important.

As the size of some commercial banks grows, the quality of the data in an integrated information system becomes even more important. Unless the systems are properly designed and accessible, lower echelon personnel may be unable to enter key data. Fewer people in a decision-making loop may speed operations and make them more efficient, but that cannot guarantee that the best decisions will be made. This criticism is widely expressed in commercial banking, but its validity and the actual trends relating to authority concentration or delegation during the 1990's are not clear. Nevertheless, the process of simplifying and shifting decision making is underway, and demand for intermediate level managers, personnel specialists, and executive decision makers in bank branches is declining.

Conventional computerized spread sheet software and more powerful relational databases play important roles in the information systems used by managers and accountants. A relational database program can link information from several tables, or lists, of data into a form or report. Expert systems, which may aid these professionals in carrying out their duties, are beginning to be used in commercial banking. These forms of software strengthen management and requires that each user acquire new skills, contribute to the reduction in demand for some clerical and accounting labor, and reduce the demand for lower level managers.

Accounting technologies. The commercial banking industry continues to introduce new and more powerful systems for accounting and related tasks. Accounting and auditing systems are structured and formatted to accommodate advanced computer technologies to search for, match, and process vast quantities of data. Technology also is vital for developing automated security measures that incorporate checks, passwords, and monitoring systems to prevent fraud and theft.

Accounting systems now interface with statement writing, mailing, investment monitoring, and collections. Consistency checking systems help identify anomalies and problem areas. Account aging is used to identify loan problem areas and to try to solve payment delinquencies as soon as possible. The longer a loan goes unpaid, the lower the probability of resolving the problem. Computerization of accounting has made it easier to avoid errors. Checks and fail-safes in the systems identify and flag incompatible data.

Mortgage and other loan accounting functions are becoming more complex and demanding. Interest rate charges are more variable than in the past. Many loan interest rates are adjusted annually or more often. Shared equity mortgages and reverse mortgages are examples of the increasing complexity of bank products. Computer systems have been able to handle the growing workload without increasing clerical labor demands. On the other hand, the more diverse offering of loans has created some management and sales related career opportunities.

Even small banks tend to have sufficient computer and software capabilities to handle more complex loans and variable interest rates. While these technological changes have improved the economies of scale of very large banking operations, the greatest benefits have been in relatively small operations. Although it is difficult to determine an optimal size efficiency level for commercial banks because of changing technology, business, and consumption patterns, some current studies show a leveling off of many important scale economies in banking at around $250 million in deposits.[15] (If these studies are correct, then the current round of mergers and the trend toward larger banking institutions may be temporary.) Diffusion of new types of loans tends to be very rapid when the risks are perceived as low for the banks or when the potential market opportunities seem significant. For instance, banks like variable rate loans because they can often qualify more potential lenders, and because there is less risk over time to the bank than when a long-term loan or mortgage is placed at a fixed rate.

Newer accounting technologies also significantly reduce the demand for accounting clerks and other clerical employees, and fewer mid-level accountants are needed in branch offices. These technologies alter the skills and work patterns of auditors and senior accountants, but they do not reduce the demand for these workers.

Sales and marketing support systems. Newer sales and marketing support systems make use of the advances in integrated information systems and accounting software. Like most other businesses, commercial banks must sell their "products" to thrive. Bank marketing personnel benefit from data entry/data base systems that allow rapid access to information on market trends; consumer preferences on investments, interest rates, and services; and other potential revenue sources. These systems allow rapid access to information about the success of current offerings.

Central office sales staff can access account and customer information at their desk PC's. In the field, loan officers and other customer and company representatives can use portable computers and modems to stay in contact with the central office. They can obtain information the customer requests, and they can enter loan data and related information directly through their portable computers. Fund transfers, accounting entries, management information entries, and customer account initiation can all be done using computer technology.

Credit cards, debit cards, and smart cards

Card use and point-of-sale operations have become an essential component of banking operations. Most of the systems that integrate cards and transaction processing are regional, but nationwide systems have been developed and may significantly alter the pattern of transaction processing in this decade.

Credit cards. Credit card operations have been a bright spot in banking during recent years. In 1990, over 76 million Americans had commercial bank credit cards, and the dollar volume of transactions was approaching $250 billion per year, while credit card consumer debt stood near

[15] Hobart Rowen, "'Stealth' Issue," *The Washington Post,* October 14, 1992, p. A21.

$150 billion.[16] Although defaults on unsecured loans (that is, credit card transactions) are a problem, as are credit card theft and fraud, these operations have been profitable for some banks.

The profitability of credit cards has brought non-banks into this business. Some of the new entrants have been very successful. This is one of several factors contributing to the blurring of the distinction between commercial banks and other businesses that offer similar services.

Credit card users are aware of the level of computerization in these operations. Many merchants make rapid checks on card validity and bank acceptance prior to concluding a transaction. Automated, voice response systems are commonly used for customer inquiries. These procedures would not be possible without telecommunications involving a computer and a credit card database.

Debit cards. The ability of the electronic fund transfer systems to instantly credit and debit accounts has made possible debit card operations. Debit cards are the equivalent of an on-line check paying system. Eventually, debit card operations may displace the bulk of consumer check writing. If this occurs, the number of ATM and retail debit card transactions could grow from under 2 billion a year at the beginning of the 1990's to over 20 billion a year by the end of the decade. At the present time, however, the explosive growth in point-of-sale transactions and ATM use has not significantly affected the volume of checks processed by banks.

These cards work like credit cards, but the user's checking account is immediately charged for any transaction amount in on-line systems, or is debited within hours or days in off-line processing. A fund insufficiency often can be spotted instantly and time lags (floats), when money is earning interest in both the crediting and debiting accounts, can be eliminated or reduced.

Debit cards also can be formatted as prepaid value cards. The card contains a dollar value that declines as the card is used. Some transit systems and shopping malls use dedicated cards of this type. Now, more flexible uses are being devised, and banks, electronic fund transfer operators, and current issuers of limited use cards are preparing for expanded use and issuance of prepaid debit cards. To accelerate this process, partnership possibilities are being explored.

Point-of-sale terminals. These machines have been in use for many years, and their diffusion has proceeded to a point that many large business systems are interconnected. They will be wide spread enough in the 1990's to make debit card operations commonplace in all large urban areas in the United States. Supermarkets and gas stations are the main users at the present time. Merchants install computer-controlled electronic checkout terminals that accept the debit cards banks issue to their customers. The same cards operate automatic teller machines. The point-of-sale networks require cooperation between merchants and banks. A central, clearing operation is generally required. This process eliminates many clerical steps, paper checks, and it reduces document shipping and handling.

Smart cards. Credit and debit cards use numbers and magnetic strips to establish their operational validity. The strips contain numeric information that can be read electronically. Another approach to automated card reading is through the use of integrated circuits. Transaction cards containing integrated circuits are called "smart cards." These circuits may contain permanently inscribed data, as well as data that can be altered or updated. Magnetic strips have some of this capability, but they cannot contain as much data, nor are the strips as durable as integrated circuits. Smart card chips are somewhat less vulnerable to erasure by magnets than are magnetic strips. Although smart cards are more expensive to produce, they offer increased flexibility for banking transactions and the potential for numerous and diverse uses. They also are cheaper to read and update, especially in complex transactions or uses.[17]

Output and Productivity

American banks are merging and combining operations to eliminate labor. BLS measures of output per hour of all persons employed in commercial banks indicate that productivity has increased strongly since 1981. Currently, credit cards produce much of the profits for some larger banks. During 1990-92, there was no net growth in business loans, and both businesses and individuals complained that it was relatively difficult to borrow. The commercial banks' share of business lending fell from 31 percent of the total in 1983 to 22 percent in 1992. In contrast, insurance companies increased their business lending from $202 billion in 1990 to $225 billion in 1992.[18] Congress, the Federal Reserve, and some Federal agencies began to seek ways of making the loan process simpler, specifically focused on significant risk, and more open to new and less established borrowers. The dollar volume of banking transactions growth has slowed, but the number of transactions, which BLS uses in measuring output, has risen steeply. The increase in smaller transactions is partly due to the growth in the use of automatic teller machines for cash withdrawals. ATM transactions tend to be smaller and more frequent than withdrawal transactions handled by tellers.

Output

Output in commercial banking grew strongly through much of the 1970's and 1980's. (See chart 4.) Loan vol-

[16] *Statistical Abstract of the United States 1991*, p. 510.

[17] Transaction costs data collected by Jerome Svigals, President, Jerome Svigals, Inc., 221 Yarborough Lane, Redwood City, CA 94061.

[18] Bernard Baumohl, "Are Banks Obsolete?" *Time*, June 28, 1993, pp. 49-50.

umes grew. ATM machines became common and were placed in shopping and commercial buildings, as well as in banks. The number of credit card users grew significantly, and bank trust activities also experienced growth. Output grew in most years between 1973 and 1988, but declined 1.3 percent in 1989 and then grew 6.6 percent in 1990, the last year for which BLS has published data.[19]

Between 1973 and 1990, output grew 3.8 percent annually. Between 1973 and 1979, output growth averaged 4.6 percent a year. Output growth slowed to an average of 3.4 percent in the 1979-90 period. Extremely high interest rates were a factor in the decline in banking transactions in 1980, and they helped restrain the growth in transactions during 1981. However, interest rate declines contributed to a 4.4-percent growth in output during 1982, despite the economic recession during that year. Transaction growth was quite strong during the 1982-90 period. Over this 8-year period, growth averaged 4.2 percent a year, almost as much as during the 1973-79 period.

Productivity

Productivity growth has been relatively slow in banking, although output per hour of all persons grew more strongly in the 1980's than in the 1970's. During the 1973-90 period, BLS data indicate output per hour grew 1.6 percent a year. During 1973-79, the rate of growth averaged 0.6 percent per year. Despite significant declines in output per hour in 1980, 1981 and 1989, this series indicated an average annual growth of 2.2 percent in the 1979-90 period. Between 1982 and 1990, output per hour rose at an annual rate of 3.9 percent. Since 1981, there has not been a significant increase in hours of all persons working in commercial banks. During the 1981-90 period, total hours grew 0.4 percent annually, but output rose 4.2 percent a year during this same period. Over 1973-90, hours increased 2.1 percent a year, while annual output increases averaged 3.8 percent.

Technological change played an important part in the productivity growth during the 1973-90 period. There was a significant amount of transaction computerization during the 1970's and 1980's. The use of ATM's grew, and electronic fund transfers also increased significantly. Automatic payroll deposit and automatic bill paying became more widely accepted, which reduced the need for bank tellers and clerks to process customer accounts.

Employment and Occupational Trends

Employment

The growth of employment in commercial banking has been slowing as productivity has risen and the rate of transaction growth has moderated. During the 1973-92 period, employment increased from 1,068,000 to 1,488,200, an annual rate of 1.8 percent. From 1973 to 1979, the annual rate of growth was 4.0 percent. Over the 1979-92 period the annual rate of employment growth slowed to 0.8 percent. (See chart 5.)[20]

Nonsupervisory worker employment grew more slowly than total employment. During the 1973-92 period, nonsupervisory employment increased from 852,300 to 1,060,200 at an average annual rate of 1.2 percent. From 1973 to 1979, the rise averaged 3.4 percent a year. During 1979-92, this employment increased an average of 0.1 percent a year, which was a small fraction of the rate for all commercial banking employment. The labor changes related to teller machines, bank consolidations, and office automation have most affected tellers, account clerks, and other nonsupervisory employees.

Women employees in commercial banking increased in number from 707,700 in 1973 to 1,116,400 in 1992. During 1973-92, employment of women rose an average of 2.4 percent yearly, considerably more than the total employment rate of 1.8 percent. During the 1973-79 period, the rise averaged 5.1 percent each year. Between 1979 and 1992, the employment of women in commercial banking went up at an annual rate of 1.2 percent.

BLS projections for employment change in commercial banking are not available. The projection from 1990 to 2005 covers the broader industry group of commercial banking, savings institutions, and credit unions. The total employment in this combined category was 2,134,600 in 1990. Commercial banks accounted for 73 percent of the employment in this group. Employment is projected to grow at an annual rate of 0.6 percent to 2,324,900 in 2005.

Table 4. Employment trends in commercial banking, 1973-92 and projection, 1990-2005

Period	Average annual rate of change[1]	
	All employees	Nonsupervisory workers
1973-92	1.8	1.2
1973-79	4.0	3.4
1979-92	0.8	0.1
1990-2005 projection (moderate)[2]	0.6	-

[1] Compound rate formula used to calculate percent changes.
[2] See text footnote 5. This projection is for commercial banks, savings institutions, and credit unions combined.

Source: Bureau of Labor Statistics.

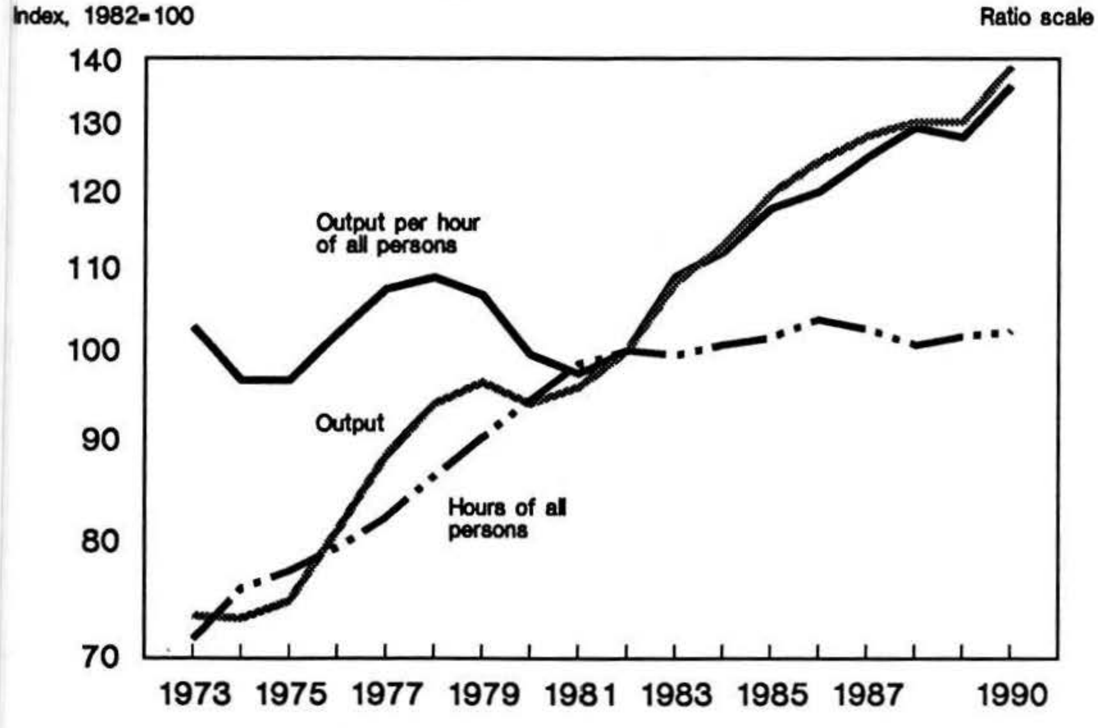
Occupations

BLS information on occupations also is available for commercial banks, savings institutions, and credit unions combined. BLS does not publish occupational data for commercial banks alone, but in 1992 commercial banks accounted for over 74 percent of employment in these three SIC's combined. Because savings and loan institu-

[19] Average annual percent change for output and productivity are based on BLS data and are calculated by the compound rate formula.

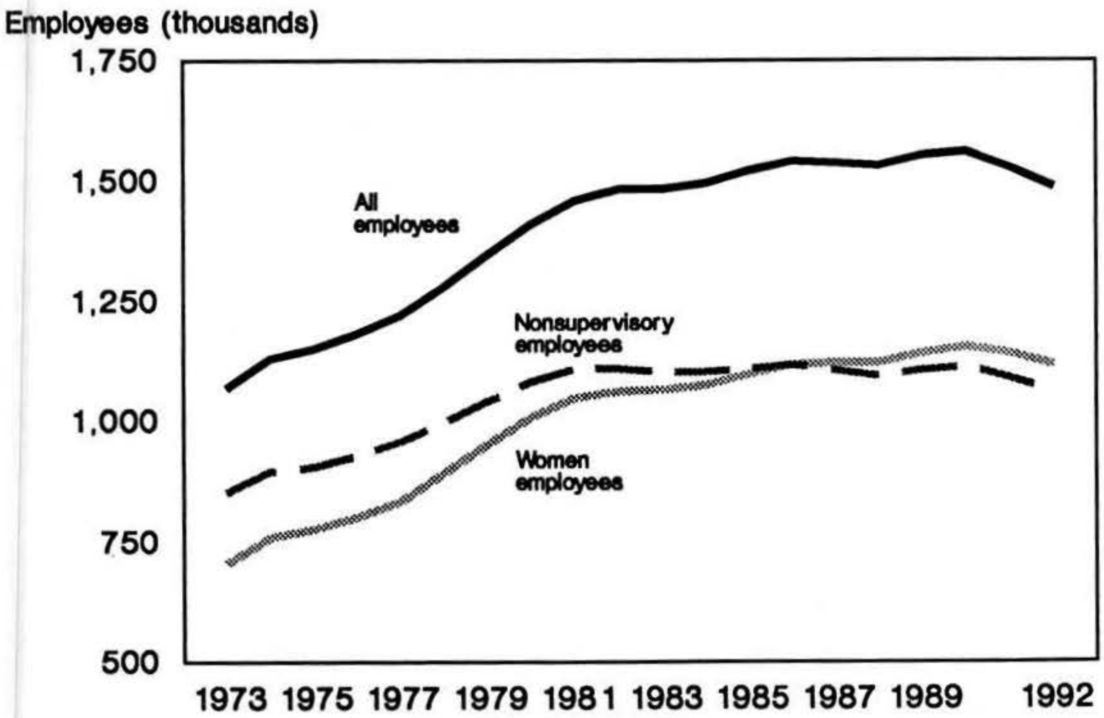
[20] Average annual percent change for employment are based on data published BLS in *Employment, Hours, and Earnings* and are calculated by the compound rate formula.

Chart 4. Output per hour of all persons and related data, commercial banking (SIC 602), 1973-90



Source: Bureau of Labor Statistics

Chart 5. Employment in commercial banking (SIC 602), 1973-92



Source: Bureau of Labor Statistics

tions are gradually becoming a less significant part of the financial service industry, commercial banks probably will experience slightly more employment growth than is projected for the combined group. (See chart 6.)

The number of nonsupervisory workers as a proportion of all workers in commercial banking has been declining. Automation has contributed to this decline. Administrative support occupations, including clerical positions, are projected to experience no significant net job growth between 1990 and 2005. In 1990, there were 1,486,000 workers employed in this group. The moderate projection for 2005 is 1,493,000. Most clerical occupations are projected to experience less than 1 percent annual employment growth.

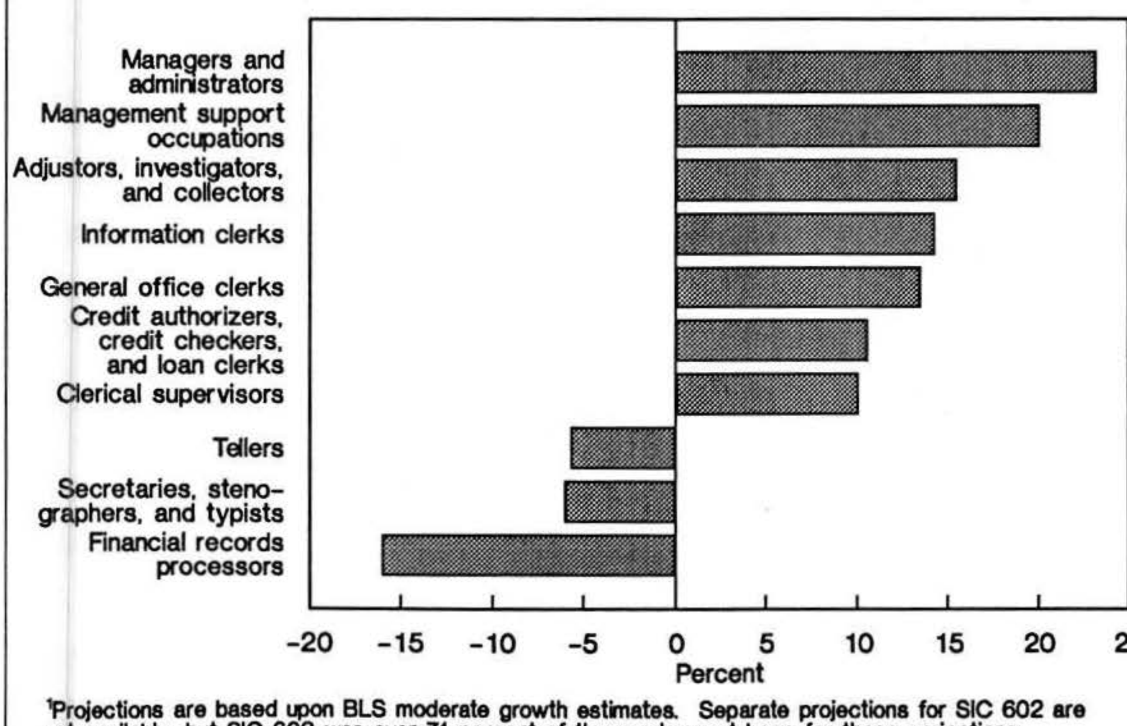
Telephone and switchboard operators; financial records clerks; mail clerks and messengers; secretaries; stenographers and typists; and duplicating, mail, and other office machine operators are all projected to experience slow declines in employment. The annual rates of decline vary from 0.4 percent for secretaries to 2.2 percent for telephone operators.

The largest single group of workers in banks and related institutions is the bank teller group. The employment of bank tellers is projected to decline from 505,000 in 1990 to 477,000 in 2005, an average annual rate of decline of 0.4 percent.

Employment growth is projected for the executive, administrative, and managerial occupations. The total number of these workers is projected to rise from less than 514,100 in 1990 to nearly 625,700 in 2005. The average annual rate of employment growth in these occupations is projected to be 1.3 percent. The major occupational groups within this category include financial managers, general managers, and top executives. Financial managers are projected to experience the strongest rate of employment growth. There were 121,680 financial managers in 1990, and the projection is for a growth rate of 2.0 percent per year to over 164,000 in 2005. The management support occupations are projected to experience a 1.2-percent growth rate, from just under 250,000 employees in 1990 to just over 300,000 in 2005. Over 40 percent of these employees are loan officers and counselors. The number of loan officers and counselors is projected to grow 1.1 percent a year from nearly 118,900 in 1990 to slightly over 140,000 in 2005.

Employment in professional specialty occupations is projected to grow 2.3 percent a year from 43,850 in 1990 to over 62,100 in 2005. The largest group of workers in this category consists of systems analysts and computer scientists. The BLS projection is for these workers to experience a 3.1-percent employment growth rate from 17,825 in 1990 to nearly 28,270 in 2005.

Chart 6. Projected changes in employment in commercial banks, savings institutions, and credit unions (SIC's 602, 603, 606) by selected occupations, 1990–2005[1]



[1]Projections are based upon BLS moderate growth estimates. Separate projections for SIC 602 are not available, but SIC 602 was over 74 percent of the employment base for these projections.
Source: Bureau of Labor Statistics

Adjusting to technological change

The adjustment of workers to technological change is an important issue in commercial banking. This industry has been receptive to introducing new technology and methods, and bank management is committed to providing the training needed to properly use office automation and other technology. Banks exhibit strong interest in training programs designed to update and maintain the skills and knowledge of nonsupervisory workers, as well as providing ongoing training for managers. The banking industry has learned from experience that expensive technologies can only be cost efficient in the hands of managers and staff members who understand how to use these new tools. Banks tend to put human resources and institutions at the center of change. Banks look carefully at ways in which technology can be used to modify traditional organizations and responsibilities. They also examine how existing institutional arrangements may retard the acceptance of technology and work patterns.[21]

Banks strive to provide workers with a defined and stable environment. For routine work, banks look for workers who accept supervision and can deal with repetitive and concrete work patterns. However, changing technology and business patterns require some workers who can operate in ill defined and ever-changing environments. These workers also must cope with nonroutine and abstract work processes. Managers must be able to act decisively, handle broad responsibilities, promote interactive group and team work, and understand the evolving comples technologies. There are growing demands for people with specialized, technical knowledge, who can set and adapt strategic goals, and who have excellent communication and motivational skills. Mid-level workers need to demonstrate an ability to work well with customers and to promote the bank's products. Automation will eliminate many clerical and teller positions.[22]

Although some bank training is informal and almost all banks provide entry-level and on-the job training, a substantial number of banks—especially the larger ones—maintain formal training centers, or use training contractors. Academic stipends are common for professional workers and managers, and the American Institute of Banking offers academic-quality training. Much of the training involving new technology is provided by vendors and contractors. Because of the growth in the variety of savings instruments and loan types, customer service representatives and loan officers are given training to help them understand fully the nature of the products that are offered to businesses and the public. Sales and marketing support systems involving programmed, computerized training and role playing are undergoing a period of rapid development and wide-spread acceptance.[23]

Computer-based training is used to educate employees in some areas of banking operations. A large and growing number of programs rely on technically advanced equipment and computers instead of (or as a supplement to) human instructors. When used in on-line systems, the courseware, as computer based training programs are called, can be updated from a central location, and the changes appear immediately throughout the network. Because the program always is accessible, a supervisor can put employees on a training program during slow periods in the work shift.

In addition to honing skills and imparting knowledge, the need to maintain the employee's interest in training has tended to promote the acceptance of interactive videodiscs, which combine computer graphics and video images or film into multimedia packages that are both entertaining and educational. Touch screen technology often is used to aid students in proceeding through the lessons. Some banks and cooperative efforts by bank groups use satellite hook-ups to broadcast television training programs.[24]

More specialized equipment and a growing complexity in the variety of work performed by bank tellers and other technical workers have lengthened the period required to train these workers to a point where they can function without constant supervision. Most tellers now require at least a month of both on-the-job training and instruction in a classroom or training area. Tellers are expected to be knowledgeable about bank services and customer offerings. Tellers now are more likely to be formally trained in referrals, product promotion, and in courtesy. Tellers also receive training in how to deal with robbery situations.

Unionization is rare in banking, and most employees are not covered under collective bargaining agreements.

There is a wide-spread commitment in banking to retraining proven employees, rather than hiring new employees for new tasks. As explained above, the opportunities available to nonsupervisory employees who are displaced from secretary, teller, and other positions will be primarily in sales and customer services. However, training and academic stipends are sometimes offered to help employees advance into specialized fields, professional work, and bank management.

On-the-job work injuries in banking are not a major issue of concern. Nevertheless, there are problems related to working at keyboards and video display terminals. Some efforts are being made to improve the design of equipment. Employees may be offered more varied work activity to avoid repetitive motion injuries, such as carpal tunnel syndrome, and there are equipment changes and additions designed to reduce the risk of injury.

[21] Olivier Bertrand and Thierry Noyelle, p. 13.
[22] Ibid, p. 41.

[23] Michael Volano, "Bank Technology's Biggest Hits of 1988," *Bankers Monthly,* December 1988, pp. 43-53, and Michael Volano, "That Personal Touch in Personal Trust," *Bankers Monthly,* June, 1990, pp. 33-40.
[24] Van Collie and Shimon Craig, "Bank Technology Teachers," *Bankers Monthly,* September 1990, pp. 62-63.

Issues relating to work area air quality, noise, and toxic substances in the work place also are receiving more attention than in the past. Newer printers and other office equipment tend to be much quieter than a few years ago. Photocopy equipment offers employees more protection from burns and cuts. Banks are beginning to measure electromagnetic field emissions. Within a few years, these field emissions may be reduced and workers protected from long-term exposure to strong fields. Ergonomics is used more as a core consideration in furniture design.

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Other BLS Publications on Technological Change

The Following BLS bulletins appraise the major technological changes emerging in the covered industries and discuss their current and potential impact on productivity, employment, and occupations. Bulletins are available for reference at Government depository libraries and at many public and school libraries.

Technological Change and Its Impact on Labor in Four Industries (Bulletin 2409, 1992), 49 pp. (Coal mining, pharmaceutical preparations, metalworking machinery, and eating and drinking places).

Technology and Labor in Copper Ore Mining, Household Appliances, and Water Transportation Industries (Bulletin 2420, 1993), 41 pp.

Outlook for Technology and Labor in Hospitals (Bulletin 2404, 1992), 22 pp.

Technology and Its Impact on Employment in the Life and Health Insurance Industries (Bulletin 2368, 1990), 38 pp.

Technology and Labor in Three Service Industries: Utilities, Retail Trade, and Lodging (Bulletin 2767, 1990), 38 pp.

Outlook for Technology and Labor In Telephone Communications (Bulletin 2357, 1990), 18 pp.

Technological Change and Its Labor Impact in Four Industries (Bulletin 2316, 1988), 41 pp. (contract construction, railroad transportation, air transportation, and petroleum pipeline transportation)

Technology and Its Impact on Labor in Four Industries (Bulletin 2362, 1986), 47 pp. (lumber and wood products, footwear, hydraulic cement, and wholesale trade)

Technology and Its Impact on Labor in Four Industries (Bulletin 2242, 1986), 46 pp. (tires, aluminum, aerospace, and banking)

The Impact of Technology on Labor in Four Industries (Bulletin 2228, 1985), 46 pp. (textiles, paper and paperboard, steel, and motor vehicles)