Computer manufacturing enters a new era of growth

Strong gains in output and employment are estimated to 1995; not surprisingly, the most optimistic of three projections does not match the extraordinary pace the industry has set in the last 25 years

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From the early 1960's through the mid-1980's, the outlook for growth in the computer manufacturing industry was, for most of the period, unusually optimistic. Even the 1981–82 recession seemed to have little effect on the industry's growth. In 1985, however, the outlook for the industry clouded considerably. Business demand for computers fell, as well as the demand for home computers. Some companies reported huge losses, and several went bankrupt. Even firms in Silicon Valley, an important center for computer manufacturing, laid off workers. The industry is now apparently at a turning point, entering an era of slower growth.

To provide some insights into the current situation, the Bureau of Labor Statistics undertook a study that focused on the development of alternative projections of industry output and employment. This article presents the results of that study.

For several decades, the Bureau of Labor Statistics has developed projections of the U.S. economy under alternative sets of assumptions. The latest set of three projections, to 1995, were published in the November issue of the *Monthly Labor Review*.[1] These and previous BLS projections were based on alternative macroeconomic assumptions, such as the unemployment rate, productivity growth, and labor force growth. While the projections for the computer manufacturing industry presented in this study reflect the recent economic projections, industry alternatives that assume different circumstances regarding the pace of technological development in the industry are also explored.

The results of this study are based on the assumption that although significant technological advances will be forthcoming during the projection period, none will have the dramatic impact of the introduction of the minicomputer in the mid-1960's or the microcomputer in the mid- to late 1970's. The analysis shows rates of projected growth of both output and employment varying significantly under the alternative scenarios. In all scenarios, the growth rate for the computer manufacturing industry is projected to exceed the average for the economy as a whole and to have one of the highest growth rates among manufacturing industries. However, the highest projected growth rate is still below that experienced over the past decades. This should come as no surprise given the rapid expansion of the industry and its present size.

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Historical overview

Over the last 25 years, the computer and peripheral equipment manufacturing industry (SIC 3573-4)[2] has been one of the more dynamic and fastest-growing industries in the U.S. economy. Industry products represented more than 20 percent of all business investment in 1984, and computers are one of the few manufacturing industries in which the United States still shows a sizable world trade surplus, estimated at $6.8 billion in 1985.[3] In addition, computers recently have become a factor in purchases of goods by households. Virtually nonexistent in 1975, personal computers are now estimated to be in 10 percent of households. Employment growth in the computer manufacturing industry has also played an increasingly more important role in the economy. With employment growth averaging more than 6 percent annually from 1960 through 1984, the industry has been adding new jobs at a rate 10 times faster than for all manufacturing.

Technological development. The development of the computer manufacturing industry can be traced, in part, through a continuous stream of technological breakthroughs in computer engineering. These advances, primarily in the area of miniaturization, have transformed the computer from a "30-ton" monster to a 2- or 3-pound machine small enough to sit comfortably on a person's lap.

Prior to 1965, the industry primarily produced large mainframe computing systems. Annual unit sales grew on average by 33 percent between 1960 and 1964. (See table 1.) Because of the size and expense of these systems, most buyers or lessees were large institutions, such as banks, insurance companies, or government agencies.

The still young industry recognized the potential demand for a smaller and less expensive system than the mainframe. This led to the development of the minicomputer. Introduced in 1965, the "minis" were very well received and for the next 10 years annual unit sales increased on average by 50 percent. (See table 1.) However, because minicomputers were much cheaper, the dollar value of sales grew less rapidly, at an average annual rate of about 10 percent.

Increased miniaturization, declining component costs, and other technical developments led to the introduction of the personal computer in 1975. Initially developed by enterprising computer engineers and sold in kits via mail order, the personal computer since has become the dominant product of the industry in terms of unit sales, accounting for more than 96 percent of domestic consumption for all computers. Over the 1975–84 period, annual growth in unit sales of the personal computer averaged 95 percent. On a value basis, however, personal computers represent only 35 percent of industry sales because the unit prices of personal computers are much lower.

Capital expenditures. Throughout the 1960's, business investment in computer equipment grew 10 percent a year, on average, or at roughly the same rate as overall capital investment. Purchases of computer equipment represented, on average, a relatively constant 3 to 4 percent of all capital expenditures. However, beginning about 1970, businesses started to devote more of their investment dollars to computerizing their operations and, as a result, the share of total business investment expenditures attributed to computers grew to 9.6 percent in 1979. (See table 2.)

Emerging from the high inflation period of the 1970's, marked by increased labor costs and increased competition from abroad, American industry began searching for a means to increase productivity by modernizing plants and

Table 1. Domestic consumption of micro, mini, and mainframe computers,[1] 1960–84

[Dollars in millions]

Year	Total		Micro				Mini				Mainframe			
			Units		Dollars		Units		Dollars		Units		Dollars	
	Units	Dollars	Number	Percent of total	Number	Percent of total	Number	Percent of total	Number	Percent of total	Number	Percent of total	Number	Percent of total
1960	1,790	$ 590.0	–		–		–		–		1,790	100.0	$ 590	100.0
1961	2,700	880.0	–		–		–		–		2,700	100.0	880	100.0
1962	3,470	1,090.0	–		–		–		–		3,470	100.0	1,090	100.0
1963	4,200	1,300.0	–		–		–		–		4,200	100.0	1,300	100.0
1964	5,600	1,670.0	–		–		–		–		5,600	100.0	1,670	100.0
1965	5,610	1,798.6	–		–		260	4.6	$ 28.6	1.6	5,350	95.4	1,770	98.4
1966	7,635	2,680.4	–		–		385	5.0	40.4	1.5	7,250	95.0	2,640	98.5
1967	11,920	3,968.0	–		–		720	6.0	68.5	1.7	11,200	94.0	3,900	98.3
1968	10,180	4,900.4	–		–		1,080	10.6	100.4	2.0	9,100	89.4	4,800	98.0
1969	7,770	4,302.2	–		–		1,770	22.8	152.2	3.5	6,000	77.2	4,150	96.5
1970	8,320	3,809.6	–		–		2,620	31.5	209.6	5.5	5,700	68.5	3,600	94.5
1971	10,400	4,118.4	–		–		2,800	26.9	218.4	5.3	7,600	73.1	3,900	94.7
1972	14,310	5,270.7	–		–		3,610	25.2	270.7	5.1	10,700	74.8	5,000	94.9
1973	19,270	5,768.9	–		–		5,270	27.3	368.9	6.4	14,000	72.7	5,400	93.6
1974	17,480	6,777.2	–		–		8,880	50.8	577.2	8.5	8,600	49.2	6,200	91.5
1975	23,470	6,128.3	5,100	21.7	$ 76.5	1.2	11,670	49.7	641.8	10.5	6,700	28.6	5,410	88.3
1976	49,550	6,770.1	25,800	52.1	374.1	5.5	17,000	34.3	816.0	12.1	6,750	13.6	5,580	82.4
1977	91,950	8,563.4	58,500	63.6	760.5	8.9	24,550	26.7	1,202.9	14.0	8,900	9.7	6,600	77.1
1978	152,650	10,283.9	115,600	75.7	1,098.2	10.7	29,550	19.4	1,595.7	15.5	7,500	4.9	7,590	73.8
1979	202,330	10,855.5	160,000	79.1	1,488.0	13.7	35,130	17.4	2,037.5	18.8	7,200	3.5	7,330	67.5
1980	301,850	13,431.2	250,500	83.0	2,104.2	15.7	41,450	13.7	2,487.0	18.5	9,900	3.3	8,840	65.8
1981	439,900	14,842.2	385,100	87.5	2,503.1	16.9	44,100	10.0	2,699.1	18.2	10,700	2.5	9,640	64.9
1982	793,420	17,311.3	735,000	92.6	4,190.0	24.2	47.820	6.0	2,821.3	16.3	10,600	1.4	10,300	59.5
1983	1,315,405	19,110.0	1,260.000	95.8	5,300.0	27.7	45,420	3.4	3,330.0	17.4	9,985	0.8	10,480	54.9
1984	2,182,005	22,295.0	2,100,000	96.2	7,750.0	34.8	72,130	3.3	4,185.0	18.8	10,700	0.5	10,360	46.4

[1] Micro, mini, and mainframe are defined in terms of price: micro–$1,000 to $19,999; mini–$20,000 to $249,999; mainframe–$250,000 and over.

NOTE: Because microcomputers exclude units with list prices less than $1,000, the sales of most personal home computers are not reflected in these figures.

SOURCE: Computer and Business Equipment Manufacturers Association.

curtailing labor costs. The computer manufacturing industry encouraged increased use and extended applications of the computer as one possible solution. Manufacturers began offering microcomputers that were built with mass-produced microprocessors and invited anyone who was interested to write the software. The result for the computer buyer was hardware and software that were both more adaptable and less expensive than the minicomputer. Aided further by changes in the tax treatment for capital expenditures in the Economic Recovery Tax Act of 1981, businesses generally responded by increasing capital spending and by devoting a larger share to computers. Business investment in computers surged over the 1980–84 period and increased from 12 percent of total investment in 1980 to more than 20 percent in 1984. (See table 2.)

Foreign trade. America's early lead in computer technology allowed U.S. manufacturers to dominate world markets during most of the 1970's. U.S. exports of computers grew from $1.3 billion in 1972 to more than $4 billion in 1978 (both stated in current prices). In the late 1970's, imports began to appear in U.S. markets. However, despite foreign competition, the computer industry's trade balance continued to grow, peaking in 1981 at $7 billion.

Since 1981, however, trade surpluses have been declining steadily, in part because of competition from East Asian and Pacific Basin countries. As a result of a number of factors, including intense price competition, many U.S. computer manufacturing companies moved their production operations to the Far East, including Singapore and Hong Kong, which offered government incentives for local investment and lower labor and materials costs. In addition, the Japanese entered the world market using the high-volume, price-cutting techniques which they had successfully used in other electronic product markets. In 1984, however, the U.S. computer industry still had a trade surplus of $5.9 billion, as shown below (millions in current dollars):[4]

Year	Exports	Imports	Trade balance
1977	$ 3,264	$ 253	$3,011
1978	4,129	757	3,372
1979	5,500	969	4,531
1980	7,606	1,159	6,447
1981	8,652	1,647	7,005
1982	9,118	2,296	6,822
1983	10,569	4,362	6,207
1984	13,511	7,575	5,936

Personal consumption. The history of the home segment of the computer industry is short, spanning only the last 10 years. As noted, the first home, or personal, computers were produced about 1975. They came in kit form and were sold mostly to hobbyists. Fueled by technological improvements, plummeting prices, and widespread interest and publicity about computers, home computer sales grew rapidly from around 210,000 units in 1978 to more than 5 million machines in 1984.[5] This growth slackened recently and is a factor in bringing the computer industry to an important juncture—posing the prospect for much slower growth in the future than experienced over most of the last 25 years. Many initial buyers may have been caught up in the "faddish" element of the computer revolution and perhaps initially did not fully understand the limitations of the machines and the difficulties of use. As skepticism grew and price wars accelerated, consumers apparently began to delay purchases, waiting for even lower prices, for more user-friendly software, and simpler and easier to use machines.

Table 2. Purchases of producers' durable equipment, 1960–84

[1977 dollars in billions]

Year	Total business investment	Business investment, in office, computing, and accounting machinery[1]	Computing equipment as percent of total
1960	53.4	1.5	2.8
1961	52.1	1.4	2.7
1962	57.6	1.4	2.4
1963	61.6	1.8	2.9
1964	68.9	2.0	2.9
1965	80.9	2.3	2.8
1966	91.9	3.1	3.4
1967	90.7	3.2	3.5
1968	95.3	3.2	3.4
1969	102.6	4.0	3.9
1970	100.0	4.0	4.0
1971	99.4	4.0	4.0
1972	110.4	4.9	4.4
1973	130.1	5.7	4.4
1974	132.0	7.0	5.3
1975	116.4	6.4	5.5
1976	123.7	8.1	6.5
1977	143.1	10.0	7.0
1978	162.8	13.0	8.0
1979	173.0	16.7	9.6
1980	167.7	20.2	12.0
1981	174.4	25.8	14.8
1982	162.6	29.4	18.1
1983	174.4	34.3	20.2
1984	209.9	43.5	20.7

[1] Data available only at SIC 357 or three-digit level; however, SIC 3573-4 accounts for approximately 95 percent of SIC 357.

SOURCE: U.S. Department of Commerce, Bureau of Economic Analysis, National Income and Product Accounts, converted to 1977 dollars by the authors, using BLS industry price index.

Employment. The computer manufacturing industry has also experienced dramatic changes in employment. From 1960 through 1984, employment growth averaged more than 6 percent annually, while employment growth for all of manufacturing averaged only 0.6 percent. As a consequence, computer manufacturing accounted for nearly 14 percent of the growth in wage and salary employment in manufacturing over the 1960–84 period, although in 1984 it still represented less than 2.5 percent of all manufacturing jobs. (See table 3.)

Although overall employment in the computer manufacturing industry has been increasing, the percentage of employees in production occupations has been declining. In the mid-1960's, when the industry was producing mainframe and minicomputer systems, production worker employment was as high as 47 percent of the total. However, the ratio steadily declined with a growing emphasis on research and

development activities, expanding at a rate of almost 18 percent annually, along with continuing automation of the production line. A slight resurgence in production employment occurred in the first few years of the personal computer. As new companies entered the market at a rapid pace, production workers were actually increasing faster than overall industry employment, reaching 41 percent of industry employment in 1979. Since then, growth in production-related occupations has slowed owing to the concentration on research and development expenses, increased automation of the production line, and the movement offshore of production facilities.

Currently, more than 25 percent of employment in the computer manufacturing industry consists of engineers, technicians, and systems analysts. The relatively high concentration of these occupations can be explained by the high priority of research and development operations. In 1983–84, computer manufacturers spent more than $6 billion on R&D activities, representing more than 7 percent of sales.[6]

In contrast to the high percentage of engineers, technicians, and computer analysts employed in the computer manufacturing industry, only 38 percent of all employees were in production-related occupations in 1984. This is one of the lowest ratios of production workers to total employment for any manufacturing industry, far below the manufacturing average of 68.7 percent. Here are the data for 1967–84:

Year	*Wage and salary employees (thousands)*	*Production occupations (thousands)*	*Ratio of production occupations to total*
1967	145.1	68.2	.47
1970	193.8	75.0	.39
1975	210.4	76.9	.37
1977	239.1	95.8	.40
1979	318.9	131.4	.41
1982	403.3	153.4	.38
1984	460.9	174.3	.38

Projections

What follows is a number of different scenarios for output and employment growth of the computer industry over the 1984–95 period. (See table 4.) Nine scenarios were developed by combining three possible assumptions concerning implementation rates of technological advances along with the three levels of overall economic growth, described in the article entitled "Economic outlook to 1995: new assumptions and projections," which appeared in the November 1985 issue of the *Review*.

Output and employment projections reflecting the combination of the medium technological implementation rate with the varying economic growth levels were developed by the model described in the above article.[7] Additional output projections were made by pairing assumptions reflecting both a lesser and greater rate of technological development and implementation with each of the same three levels of economic growth and then analyzing the resulting expected impact on demand, production, and employment.[8]

Although there are nine alternative scenarios, the emphasis in this article is on the following three: low rate/low economic growth, medium rate/medium economic growth, high rate/high economic growth. These three scenarios will be referred to subsequently as the low, medium, and high scenarios.

A breakdown of the projected annual growth rates during the 1984–95 period for the components of demand is shown in table 5. The projections for the medium case were taken directly from the macro projections in the November article. The projected growth rates for the low and high scenarios were estimated through analysis of the possible interaction between the technological rates and the various rates of economic growth. This analysis by its nature was judgmental and subjective, particularly in that the assumed rates of technological use are broad in nature and are not specific to any given technology.

Before continuing, a caveat is in order. The constant dollar value of the computer manufacturing industry's output is difficult to measure because of the combination of unit price declines and increased unit capabilities, especially over the last several years. This problem arises because the fast pace of technological development, especially for the microcomputer, virtually redefines the product within a period of a few years. Consequently, it is difficult to make a unit price comparison as the product "unit" is not strictly comparable over the period of technological change.

In December, the Bureau of Economic Analysis released a new deflator for this industry. The deflator increases the historical real output of the computer manufacturing industry, compared with the real output as measured by the defla-

Table 3. Total employment for all of manufacturing and computer manufacturing, 1960–84, selected years

[Numbers in thousands]

Year	Total manufacturing	Computer manufacturing	Computer manufacturing as percent of total
1960	17,152	116	0.7
1965	18,400	148	.8
1970	19,664	236	1.2
1975	18,614	238	1.3
1976	19,305	239	1.2
1977	20,014	262	1.3
1978	20,851	297	1.4
1979	21,401	339	1.6
1980	20,668	376	1.8
1981	20,559	407	2.0
1982	19,154	424	2.2
1983	18,825	440	2.3
1984	19,779	479	2.4
	Average annual rate of change (compound rate)		
1960–84	0.6	6.1	–
1960–65	1.4	5.0	–
1965–70	1.3	9.8	–
1970–75	−1.1	0.2	–
1975–80	2.1	9.6	–
1980–84	−1.1	6.2	–

SOURCE: Bureau of Labor Statistics data compiled from Current Employment Survey; prior to 1967, computer employment data are from Department of Commerce, *County Business Patterns*.

Table 4. Output and employment in computer manufacturing under alternate projections of economic growth and technological development, 1984–95

[1977 dollars in millions]

Rate of technological development	Economic projections			Compound annual rate of growth[1]		
	Low	Medium	High	Low	Medium	High
Output						
Low	$78,773	$92,915	$106,857	5.7	7.3	8.6
Medium	92,793	104,315	117,846	7.2	8.4	9.6
High	102,861	122,107	138,300	8.3	10.0	11.2
Employment						
Low	627,000	685,000	715,000	2.5	3.3	3.7
Medium	679,000	713,000	741,000	3.2	3.7	4.1
High	705,000	723,000	760,000	3.6	3.8	4.3

[1] In 1984, output was $43,021 million, and employment totaled 479,000 jobs.

NOTE: See text for discussion of problems of measuring constant dollar output. Employment covers wage and salary jobs.

tor used in this study. The Bureau of Labor Statistics has also undertaken an effort to improve measures of price changes among the range of computer products. Preliminary results of these studies indicate that the historical measure of real output on which the original projections were based is probably understated. Because this study presents alternatives to those projections, however, that output measure is used in the interest of continuity. The use of this historical output series, however, should not be construed as implying a final decision on the relative merits of alternative measures.

Technological factors. One of the most influential technological advances during the next 10 years is expected to be continued increases in computing power. This year, the first "micron" computer chips are expected to become available in the semiconductor marketplace. These chips have 4 times the storage capacity of the 256K RAM chips. Half-micron and quarter-micron computer chips with even greater storage capacity are widely predicted by the mid-1990's. Each successive generation of micron and sub-micron computer chips should spur the development of computers with increased computing power.[9]

This power should enable software designers to develop more complex programs for the personal computer. With continued advances in hardware and software, tasks that now require mini or mainframe computers can be expected to be accomplished in the future with the use of personal computers. Software also can be expected to continue to become easier to use. Additional computing power should facilitate greater use of artificial intelligence techniques in software designs, resulting in a variety of decisionmaking software that develop analytical conclusions based on user-defined parameters.

Both software and hardware are also expected to become increasingly targeted for specialty markets both in business and in the home. Doctors have a need for diagnostic and other medical software. Lawyers require specialized word-processing software. Other markets include computer-aided design and engineering, scientific research and development, and total factory automation. Small businesses also often have specialized tasks to perform that require different capabilities than the spreadsheet, word processing, and inventory and accounting software that is generally available. This is expected to change over the course of the next 10 years as software becomes more specialized for business purposes. In the home, as well, the computer should become more accepted as a useful appliance with an increased variety of specialized programs that focus on hobbies, educational interests, entertainment, and productivity in the household.[10]

The linking of microcomputers to each other and shared data bases also is an innovation that should stimulate investment demand for computers. Businesses want the ability to communicate among their mainframes, mini-, and microcomputers regardless of the manufacturer. Through 1985, computer equipment by different manufacturers was for the most part incompatible in such a network; however, it is expected that this problem will abate through the mid-1990's.

Telecommunications networks that provide electronic banking, brokerage, shopping, and data retrieval services should play a more influential role in the future growth of the computer industry. These networks offer convenient banking, brokerage, and shopping services. They also supply a necessary adjunct to microcomputers in providing access to data bases. Telecommunications networks undoubtedly will influence the personal computer market for homes and businesses as they expand their markets and services.

The optical laser disk as a medium for data storage is another development likely to contribute to the growth of the computer industry. The optical disk can store roughly a thousand times the amount of information that can be stored on a 5¼-inch floppy disk. This makes the disk an ideal medium for data storage as an accessory to the microcomputer, which has limited ability to store raw data. The dissemination of data bases on optical disks is already a reality in the form of encyclopedias.[11]

The development of more powerful microcomputers, the increased availability of more specialized and more power-

ful software and the advances in networking, telecommunications, and optical disk technology are all expected to provide the stimulus for additional growth in the computer industry through 1995. The extent that these expected advances contribute to the computer industry's growth is dependent upon the pace of adoption. Without specific references to any given technological development, the implementation rates presented in the projection scenarios are specified in terms of their effect on growth prospects for the industry.

Business investment and government spending. A moderate rate of technological development and implementation combined with a generally favorable economy is assumed to encourage both business investment and government spending in the medium scenario. Business investment in computer equipment is projected to grow annually at a rate of 8.3 percent. Federal Government spending is projected to grow 7.1 percent annually and State and local government spending, 6.5 percent.

In the low scenario, a low rate of technological development and implementation coupled with a generally sluggish economy is assumed to hamper both business investment and government spending. Consequently, business investment is projected to have a growth rate of 5.8 percent annually. The annual growth rate for Federal spending is a projected 4.7 percent and for State and local spending, 3.6 percent.

In the high scenario, with the combination of a rapid rate of technological development and implementation and a strong, investment-oriented economy, business investment is projected to grow at an annual rate of 10.9 percent. Government spending on computers at the Federal level is projected to rise at an annual rate of 9.3 percent and at the State and local level, 8.1 percent.

Personal consumption. The growth rates projected for personal consumption of the computer are high in all three alternatives. However, the overall impact on the industry in all cases is relatively low because personal consumption only represents from 6 to 8 percent of total industry production from a value viewpoint. Personal consumption is projected at about $8 billion, reflecting a 20.9-percent annual growth rate in the moderate alternative.

In the low scenario, a slow rate of development of a wide variety of specialized, user-friendly software is assumed to somewhat reduce consumer demand. As a result, the projected annual growth rate is 15.9 percent.

In the high scenario, the assumption of a strong economy coupled with the development of a wide variety of consumer software should have a stimulative effect on personal consumption. In this alternative, personal consumption is projected to grow at an annual rate of 24.3 percent.

Foreign trade. In the medium scenario, by 1995, the foreign exchange rate of the U.S. dollar is assumed to fall gradually to the level of 1980. The world economy is assumed to roughly parallel the generally favorable economy of the United States. These assumptions combined with a moderate rate of technological implementation are expected to stimulate exports for a projected 10.5-percent growth rate. Imports are projected to have an 11.8-percent annual growth rate, reflecting a strong domestic demand for computer products.

In the low scenario, the assumptions of a continuation of a strong U.S. dollar, a generally sluggish worldwide economy, as well as a slow rate of technological development and implementation are projected to hamper the growth in U.S. exports of computer products. Under these assumptions, U.S. computer firms should continue to find competition with foreign firms difficult and to move offshore to take advantage of lower labor and materials costs to remain competitive. Exports are projected to grow at an annual rate of 7.8 percent and imports at a rate of 9.5 percent.

Table 5. Alternative projections of output and consumption for computer manufacturing, 1984–95

[1977 dollars in millions]

Item	1977	1984	1995			Compound rate of growth			
						1977–84	1984–95		
			Low	Medium	High		Low	Medium	High
Industry output	$12,920	$43,021	$78,773	$104,315	$138,300	18.8	5.6	8.4	11.2
Intermediate use	3,176	9,809	18,429	23,701	31,320	17.5	5.9	8.3	11.1
Final users:									
Personal consumption	86	1,000	5,049	8,071	10,932	42.0	15.9	20.9	24.3
Business investment	6,159	26,529	49,311	63,590	82,437	23.2	5.8	8.3	10.9
Government									
Federal	1,078	5,564	9,255	11,828	14,773	26.4	4.7	7.1	9.3
State and local	121	626	926	1,246	1,477	26.5	3.6	6.5	8.1
Exports	3,215	10,525	23,982	31,472	41,071	18.5	7.8	10.5	13.2
Imports	−493	−8,392	−22,804	−28,569	−34,274	49.9	9.5	11.8	13.6

NOTE: Consumption totals exceed industry output slightly because a small percentage of total commodity output is produced as a secondary product by other industries. See text for discussion of problems of measuring constant dollar output for this industry.

Table 6. Alternative projections of employment for selected groups in computer manufacturing, 1984–95

[Numbers in thousands]

Occupation	1984		1995 low projections		1995 medium projections		1995 high projections	
	Employment	Percent	Employment	Percent	Employment	Percent	Employment	Percent
Total employment—SIC 3573-4	479.0	100.0	627.0	100.0	713.0	100.0	760.0	100.0
Managerial and management-related occupations	75.2	15.7	98.4	15.7	111.9	15.7	121.6	16.0
Engineers	59.4	12.4	94.0	15.0	101.2	14.2	129.2	17.0
Computer systems analysts	7.7	1.6	10.7	1.7	12.8	1.8	15.2	2.0
Technician occupations	57.5	12.0	92.8	14.8	95.5	13.4	121.6	16.0
Marketing and sales occupations	13.4	2.8	21.9	3.5	20.0	2.8	21.3	2.8
Administrative support occupations	87.7	18.3	102.8	16.4	117.6	16.5	125.4	16.5
Precision production occupations	27.8	5.8	34.5	5.5	40.6	5.7	41.6	5.5
Handworking occupations, including assemblers and fabricators	80.0	16.7	81.5	13.0	109.8	15.4	98.8	13.0

In the high scenario, the following conditions are assumed: the foreign exchange rate of the U.S. dollar declines to its 1980 level at a faster pace than in the medium scenario, the economic growth of the major trading partners of the United States roughly parallels the high growth of the U.S. economy, and there is a high rate of technological development and implementation. Under these assumptions, both foreign and domestic demand for computer equipment is expected to be high. The competitiveness of U.S. computer firms should also increase under these assumptions as the cost advantage of foreign labor and materials is reduced. Export growth is projected to increase at an annual rate of 13.2 percent, while imports are projected to have an annual growth rate of 13.6 percent.

Output. The output projections derived in the alternative demand scenarios previously discussed indicate that the computer manufacturing industry should remain vigorous. The projected growth rates for output during the 1984–95 period under the various scenarios range from 5.6 to 11.2 percent. However, as seen in table 4, the range is much narrower when focusing on all but the two most extreme scenarios. These rates, while slow by historical standards for this industry, would still exceed the rates of all but a handful of manufacturing industries even under the high growth scenario.[12] The output growth projected for this industry in all scenarios would approximately double the historical relationship of the computer industry to total manufacturing.

The medium scenario would result in a projected annual growth rate of 8.4 percent, a pace nearly 3 times faster than for all manufacturing industries.[13] The low scenario reflects an industry growing only half as fast as it did between 1960 and 1984. However, at a 5.6-percent annual growth rate this still would be 2.5 times the projected rate of growth for all of manufacturing.[14] The surging demand and increased competitiveness of U.S. computer manufacturers anticipated in the high scenario results in a projected annual growth rate of 11.2 percent.

Employment. The range of projected growth for employment, varying from 2.5 to 4.3 percent annually, is much narrower than the range for projected output growth. These projections assume continued improvements in productivity, accelerating in tandem with faster output growth. The anticipated gains in productivity are due to the assumption of some continued movement to offshore manufacturing sites, improvements in the production process utilizing automation and robotics, and the introduction of simpler but more powerful components.

Employment in the medium scenario is projected to reach 713,000 by 1995. Although this means the industry would grow at half its historical rate of employment growth, it would be expanding about 6 times faster than all manufacturing industries and would be one of the fastest-growing industries in the economy.[15]

The assumption of a moderate but continuous stream of technological advances described in this scenario can be expected to foster an increase in the number of engineers, technicians, and computer systems analysts. (See table 6.) As a group, they are projected to increase 4.8 percent annually and account for 29.4 percent of industry employment, 13 percent greater than their share in 1984. Production workers, however, are not anticipated to fare as well. Assumptions of continued gains in productivity would result in a projected decline in these occupations of 6 percent in terms of proportion of industry employment.

Reduced demand resulting from the conditions described in the low scenario would likely mean intense price-competition and tight profit margins. This in turn would sharply curtail employment, projected at 627,000 in 1995. New jobs would fall to 149,000. While indicating slow growth in the computer industry, these new jobs would represent almost 50 percent of the new manufacturing jobs projected in the low growth alternative.[16]

Production workers would be the most affected in this low scenario. Assuming the continued movement of the production process overseas, handworking occupations, including assemblers and fabricators, would see their share of industry employment decline by 22 percent. Precision production occupations would decrease by 10 percent. Reduced revenues for computer manufacturers assumed in this scenario

would limit funds available for research and development, thereby lessening the rate at which new products enter the market. Under these conditions, engineers, technicians, and computer systems analysts would experience slow growth. They would, however, increase their share of industry employment as an offset to the decline of production workers.

Given the overall favorable conditions for domestic manufacturing coupled with accelerated implementation of technological advances assumed in the high scenario, employment in this industry is projected to reach 760,000 jobs in 1995. This would represent a vigorous 4.3-percent growth rate, nearly 17 percent faster than the rate projected in the medium scenario.

Despite the reduced movement to offshore manufacturing sites assumed in this scenario, the gap between the projected rates of growth for output and employment would continue to widen, assuming the achievement of higher productivity through technological advancements in product components and production methods. More funds are assumed to be devoted to R&D activities; therefore, engineers, technicians, and computer systems analysts are projected to more than double their 1984 employment and account for 35 percent of industry employment. Precision production and handworking occupations are projected to increase 30 percent in the high scenario. However, the share of industry employment represented by these occupations would decline nearly 18 percent as a result of assumed acceleration in productivity.

Summary and conclusions

The computer manufacturing industry has received a great deal of attention in the last 25 years. The advent of the microcomputer and the subsequent explosive expansion of output reinforced a perception that the industry's potential for growth was enormous. The slump of 1985, however, brought the realization that there were limits to this rapid growth. Given the assumptions used in this study, the computer manufacturing industry is seen as being strong and viable and likely to continue to grow, but at a less rapid rate than in the past. This is hardly surprising. The industry is maturing. Historically, the computer manufacturing industry has experienced periodic waves of rapid expansion; each wave precipitated by the introduction of a major technological advance, such as the mainframe, the minicomputer, and finally, the microcomputer. Now, after the microcomputer and without a new revolutionary computer on the horizon, the industry seems to be entering a period of stable growth that is characteristic of a maturing industry. Still, even without any new revolutionary breakthroughs anticipated through 1995, it is expected that the computer manufacturing industry will continue to be one of the strongest manufacturing industries. □

———*FOOTNOTES*———

[1] See Betty W. Su, "The economic outlook to 1995: new assumptions and projections"; Howard N Fullerton, Jr, "The 1995 labor force: BLS' latest projections"; Valerie A. Personick, "A second look at industry output and employment trends through 1995"; and George T. Silvestri and John M. Lukasiewicz, "Occupational employment projections: the 1984–95 outlook," *Monthly Labor Review*, November 1985, pp. 3–59.

[2] The Office of Economic Growth and Employment Projections uses a 156-order industry sectoring plan for projection purposes. Under this plan, SIC 3573–4 accounts for one sector. This industry sector includes manufacturers whose primary product is electronic computing and peripheral equipment and calculating and accounting machines other than electronic computing equipment. However, because the production of computers and peripheral equipment accounts for the overwhelming majority of this industry, the focus of this article is on computers and peripheral equipment.

[3] See *U.S. Industrial Outlook 1986* (U.S. Department of Commerce, International Trade Administration), p. 28–1.

[4] U.S Department of Commerce, Bureau of the Census, Foreign Trade Division data.

[5] *Statistical Abstract of the United States, 1984* (U.S. Department of Commerce, Bureau of the Census), table 1422. See also *The Wall Street Journal*, June 4, 1985.

[6] *Business Week*, Mar. 22, 1985, p. 176.

[7] Su, "Economic outlook to 1995." The following is a brief description of the three assumed economic growth levels:

High: Projected real GNP annual growth 1984–95 is 3.8 percent. Declining unemployment to 5.0 percent in 1995. High rate of business investment due to low capital costs and high profits. Declining foreign exchange rate of the U.S. dollar.

Medium: Projected real GNP annual growth 1984–95 is 2.9 percent. Declining unemployment to 6.0 percent in 1995. Strong rate of business investment. Declining foreign exchange rate of the U.S. dollar.

Low: Projected real GNP annual growth 1984–95 is 2.2 percent. Unemployment remains around 7.0 percent. Slow rate of business investment. Continuation of a strong U.S. dollar relative to foreign currencies.

In all three scenarios, the real economic growth of the Nation's major trading partners is assumed to more or less parallel that of the United States.

[8] For employment projections, see Personick, "A second look at industry output."

[9] See John W. Wilson, "Super Chips," *Business Week*, June 10, 1985.

[10] For related information, see William M. Bulkeley, "Faster Cheaper Machines Seen Edging into Growing Super Minicomputer Field," *The Wall Street Journal*, June 23, 1955, p. 6; Richard Brandt, "Finding the Missing Link in Automation," *Business Week*, June 17, 1985; Pete Carey, "The Future of the Micro—Looking Ahead at the Next Decade," *Popular Computing*, January 1985, pp. 89, 90, 178–79; and Kevin Anderson, "Personal Computers Search for a Niche," *USA Today*, June 10, 1985, p. E–1.

[11] Mark Lewyn, "Future Looks Bright for Optical Disk Systems," *USA Today*, July 17, 1985, p. B–1.

[12] Based upon projections data in the November 1985 issue of the *Monthly Labor Review*.

[13] Personick, "A second look at industry output," p. 29.

[14] *Ibid.*

[15] *Ibid*, p. 28.

[16] *Ibid.*

NOTE: Sources of additional information on topics discussed in this article include: John W. Wilson, "America's High-Tech Crises," *Business Week*, Mar. 11, 1985, pp. 56–62, 67; "Computer Industry's Rapid Growth is Slowing," *The Wall Street Journal*, May 24, 1985, p. 6; Andrew Pollack, "Computer Makers in a Severe Slump," *The New York Times*, June 10, 1985, pp. D–1, D–5; and John W. Wilson, "Computers: When Will the Slump End?" *Business Week*, Apr. 21, 1986, pp. 58–61.