Semiconductor Industry Insights—1990

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A Strategic Outlook Series Report
from Dataquest, Michael A. Ford, and William P. Hesley

Semiconductor Industry Insights—1990

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The data and analysis presented within *Semiconductor Industry Insights—1990* were developed by Dataquest, Michael A. Ford, and William P. Hesley and are based on information from Dataquest Incorporated, Dun & Bradstreet (D&B), the U.S. Department of Commerce (DOC), and the Organization for Economic Cooperation and Development (OECD).

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Preface

The semiconductor industry, in the strictest definition, comprises companies that produce semiconductor devices for sale in the open market or for internal consumption. A report on the companies that produce the semiconductors would give a picture of the industry, but not the complete picture. The complete picture emerges when the semiconductor industry is analyzed in the context of the overall structure in which it exists. And that is an interrelated structure that relies on customers, depends on suppliers, and is subject to external pressures from governments and worldwide economic conditions.

With this interrelated industry structure in mind, *Semiconductor Industry Insights—1990* integrates data and concepts from several Dataquest semiconductor services with regional economic forecasts from OECD, D&B, and the U.S. DOC. Written in executive summary style, it is intended to provide high-level, insightful analysis of the recent history and near-term future of the semiconductor industry for semiconductor users, semiconductor producers, suppliers to the semiconductor industry, investors within the industry, and interested parties who want to understand the near-term future of this industry.

Semiconductor Industry Insights—1990 was completed in July 1989 and the forecasts and projections contained within this report are based on information from several sources published in late 1988 through July 1989, as follows:

- Source
  - *Economic Outlook* (OECD), published December 1988
  - *U.S. Economic Forecast* (D&B), published April 1989
  - *U.S. Economic Outlook* (DOC), published January 1989
  - *Dataquest Electronic Equipment Forecast*, published May 1989
  - *Dataquest Semiconductor Demand Forecast*, published July 1989
  - *Dataquest Semiconductor Production Forecast*, published July 1989
  - *Dataquest Semiconductor Equipment Forecast*, published July 1989

About Dataquest

Dataquest is a worldwide market research company, headquartered in San Jose, California (Silicon Valley). Dataquest employs more than 700 people worldwide and operates market research resources in Japan and other Pacific Rim locations, Europe, and the United States. As a subsidiary of Dun & Bradstreet, Dataquest has access to major economic forecasting and business data bases. In addition, through its own worldwide research resources, Dataquest has compiled the most comprehensive integrated data base in the world covering the semiconductor industry and its suppliers and customers.

Dataquest's Data Base

The Dataquest data base is created by research involving ongoing conversations with some 250 different companies worldwide, surveys, examination of public business disclosures such as annual reports from more than 200 other companies, and data made available by Dun & Bradstreet.

This data base provides the underlying data and is the basis for trend analysis and forecasting at an extraordinarily detailed level for all companies within the electronics industry. Dataquest provides 11 different client services in which the data, analysis, and forecasts are presented in detailed reports, newsletters, and on-line terminal access to the data. These 11 client services are aimed at the particular needs of specific participants within the electronics industry; these services and their relation to the infrastructure are illustrated in Figure i.

Semiconductor Industry Insights—1990 draws from many of the Dataquest semiconductor industry services as well as other resources available to Dataquest and presents a high-level picture of the semiconductor industry for the 1989 and 1990 time frame. More detailed information on individual subjects is available from Dataquest through subscriptions to the appropriate service.

Figure i

Dataquest's Semiconductor Industry Services

Services	SUIS Semiconductor User Information Service	ASETS Asian Semiconductor and Electronics Technology Service JSIS Japanese Semiconductor Industry Service ESIS European Semiconductor Industry Service SIS Semiconductor Industry Service JSAM Japanese Semiconductor Application Markets ESAM European Semiconductor Application Markets NASM North American Semiconductor Markets SAM Semicondutor Application Markets MilAero MilAero Technology Service	SEMS Semiconductor Equipment and Materials Service
Audience	Semiconductor Buyers	Semiconductor Producers	Semiconductor Equipment and Materials Producers

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Source: Dataquest September 1989

CHAPTER 1

Introduction

With the first-half results of 1989, the semiconductor industry appears to be continuing the healthy expansion of the past three years. In 1988, worldwide semiconductor industry revenue was $50.5 billion. This represents a healthy 32.0 percent growth over 1987 and a doubling of annual revenue in just three years since the 1985 recession.

Continued strength of the semiconductor industry in 1989, 1990, and beyond will depend on many worldwide factors, which include the following:

- The continued growth of the economies of the United States and its major trading partners
- The resulting capital spending—with its high content of electronic equipment—in the major industrialized regions of the world
- The continuing demand for semiconductors from producers of electronic equipment within each major industrialized region of the world
- The evolution of semiconductor manufacturing technology
- A continuing flow of new semiconductor products that enable innovative electronic products to stimulate the economies of all regions

Semiconductor Industry Insights—1990 provides information and insights about how these factors combine to form and influence the industry infrastructure. These worldwide factors extend beyond the boundaries of companies, governments, and geographic regions. Implicit in these factors is a complex buyer-seller chain in which buyers create demand that pulls products through the chain. This complex chain consists of several tiers, beginning with the demand for electronic equipment, continuing to semiconductor devices, and ending with the demand for semiconductor equipment and materials. Demand for various products flows through the buyer/seller chain from one level to the next, producing a cascading "waterfall of demand," as shown in Figure 1-1.

This waterfall of demand is so fundamental to understanding the industry and the material presented that we have organized this report to follow the waterfall.

Organization of this Report

Information, analysis, and insight are presented within each level of the waterfall so that the reader can understand the infrastructure as it relates to him or her. The issues and economic influences are quite different depending on the level within the waterfall where one sits. The perspective also is different based on whether one has an investor's, banker's, buyer's, or seller's point of view. Figure 1-2 illustrates the different perspectives within the electronics industry infrastructure. Interest in various sections of the report and levels of the waterfall will depend on the reader's individual perspective.

Additionally, investors, bankers, and other interested parties may be interested in all perspectives of the industry.

Chapters Follow the Waterfall

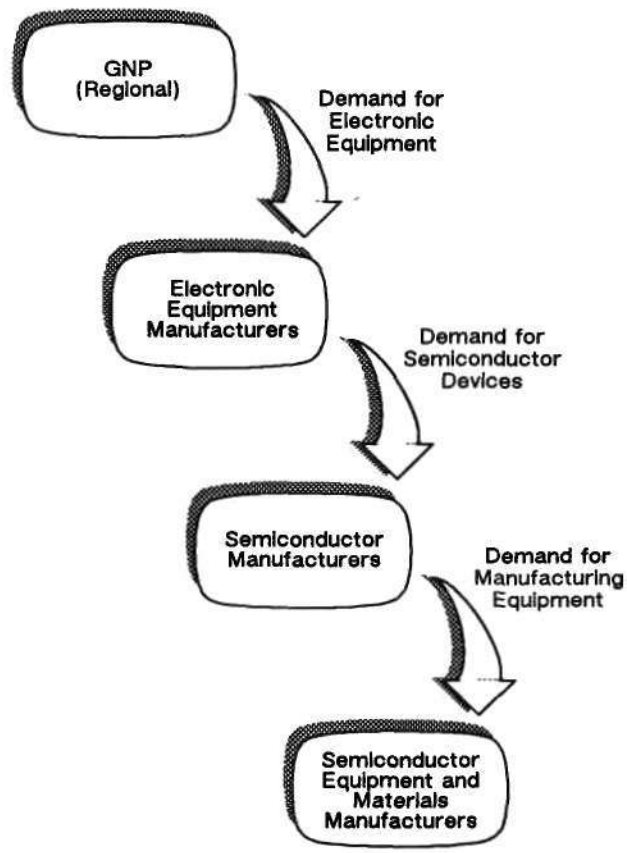
As stated earlier, the purpose of this report is to provide the reader with high-level, insightful analysis of the recent history and near-term future of the semiconductor industry.

Chapter 1 establishes the various reader perspectives and defines terminology.

Chapter 2 provides critical background information leading to 1989 semiconductor industry conditions and describes the industry infrastructure in terms of the demand waterfall.

Figure 1-1

Waterfall of Demand



0004672-2

Source: B. Healey & M. Ford

Chapter 3 provides a forecast of the worldwide and regional economic conditions. The individual regional economic conditions form the "headwaters" of the waterfall of demand and thus establish the demand and production levels of electronic equipment within each region.

Chapter 4 develops the relationship between regional economic factors and electronic equipment demand and production. The chapter ends with the worldwide forecast of semiconductor purchases by electronic equipment manufacturers.

Chapters 5 and 6 identify regional demand and production of semiconductor devices.

Chapter 7 presents the bottom levels of the demand waterfall, which are the resulting demand and production of semiconductor manufacturing equipment and materials.

Chapter 8 provides a summary of key issues and observations.

An investor or lender naturally will be interested in both the economic overview and resulting electronic equipment production forecast of Chapters 2 and 3, as well as the chapter presenting the perspective that matches his or her business interest.

Terminology and Definitions

Throughout this report, the terms "market," "consumption," "demand," "production," "output," "sales," and "revenue" have and will appear frequently. In addition, various economic terminology is used throughout. Precise definitions of these terms are given in the following paragraphs.

The terms "market," "consumption," and "demand" refer to the dollar value of products purchased within the specified geographical region, (e.g., North American and worldwide) regardless of where the products were manufactured.

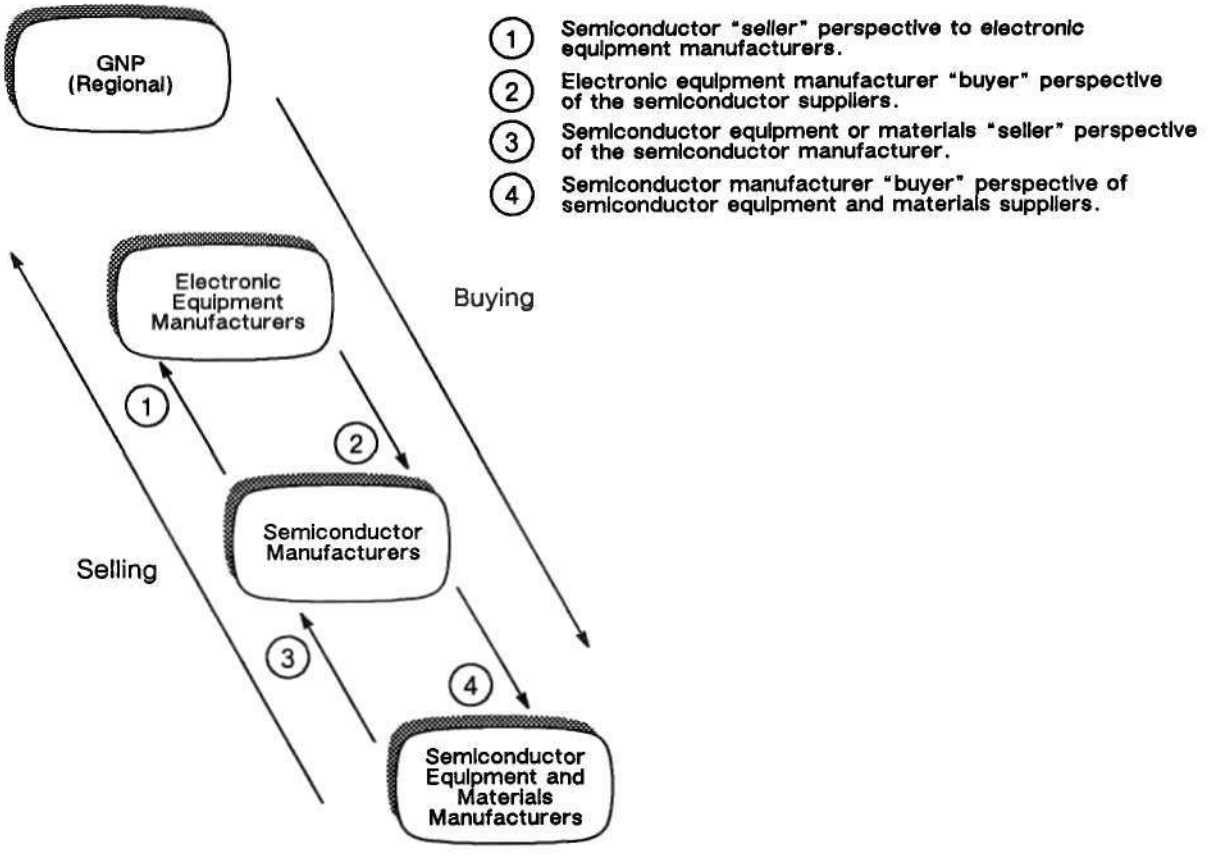
The terms "production," "output," "sales," and "revenue" refer to the if-sold dollar value of products manufactured within the specified geographical region, regardless of where these products are purchased (i.e., purchased within the specified region or exported to another).

On the basis of the above definitions, assuming constant levels of inventory, worldwide production or sales equals worldwide demand or consumption.

The terms "real GNP" and "real GDP" refer to the gross national product and the gross domestic product of a country or major world region. The GDP is the total market value of all goods and services produced each year within the domestic borders of a country. The GNP equals the GDP plus the net of foreign investment income to domestic residents less income earned in the domestic market by foreign investors.

Figure 1-2

Reader Perspectives



0004672-3

Source: M. Ford & B. Hesley

GNP/GDP also equals the sum of domestic demand plus exports minus imports. The three components of domestic demand are consumer spending, private fixed investment, and government spending.

The term "real" as applied to GNP, GDP, and other expressions refers to the value in constant prices prevailing in a reference year, which is 1982 for the U.S. dollar. The term "nominal" as applied to GNP/GDP refers to the value at today's prices.

The terms "current account," "external account," or "external balance" refer to the difference between total exports and imports of goods and services, usually for one year.

The terms "private fixed business investment" and "private fixed nonresidential investment" both refer to investment in capital goods or capital spending by businesses and exclude residential investment. The term "private fixed investment" is the total of business capital spending and residential investment.

Dataquest Industry Classifications

Semiconductor Consumer Application Market Segments

Dataquest has categorized semiconductor consumers into the following six end-market application market segments:

- Data processing
- Communications
- Industrial
- Consumer
- Military
- Transportation

Semiconductor Product Classifications

Semiconductors are classified as either integrated circuits or discrete devices. Within these classifications are further specific product definitions, outlined as follows, and illustrated in Figure 1-3:

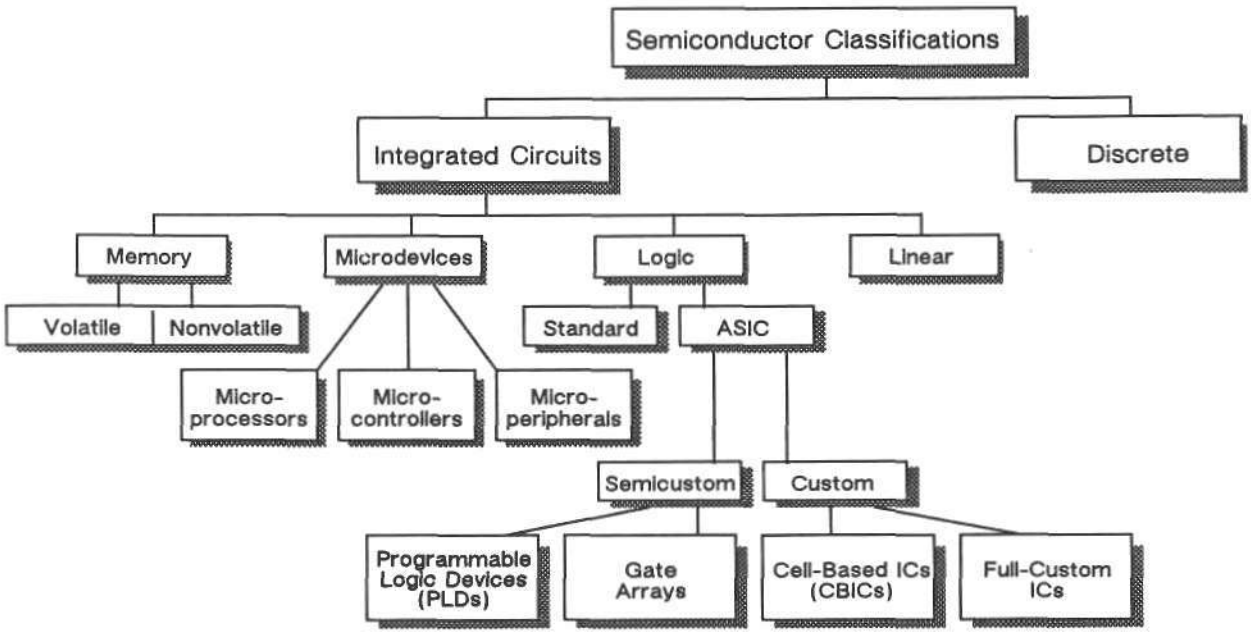
- Discrete devices are further classified as transistors, diodes, thyristors, optoelectronics, or other discrete devices.
- Integrated circuits are further classified into functions such as memory, microdevices, logic, and linear.

All semiconductor devices are further classified by various process technologies, shown as follows:

- Bipolar digital—TTL, ECL, and other
- MOS—NMOS, PMOS, CMOS, and BiCMOS

Figure 1-3

Semiconductor Product Classifications



0004672-4

Source: Dataquest
September 1989

CHAPTER 2

Critical Points in Understanding the Semiconductor Industry's Future

Critical to understanding the future of the semiconductor industry is an awareness of the events that have led the semiconductor industry to 1989 and knowledge of the electronics industry infrastructure that supports the semiconductor industry.

Historical Perspective: Events Leading to 1989

United States Launches the Semiconductor Industry

The launch of the semiconductor industry occurred when Bell Laboratories produced the first germanium transistor on December 23, 1947. By 1952, a number of companies in the United States were producing germanium devices commercially.

By the end of that decade, Texas Instruments (TI) had begun commercial production of silicon transistors. By then, the market topped $100 million in sales, primarily to the U.S. Department of Defense (DOD) and to electronics companies for the manufacture of transistor radios.

Industry Expands to Worldwide Infrastructure

In 1959, Fairchild Camera and Instrument developed the planar technology for making transistors, which TI used in 1961 to produce the first integrated circuits (ICs). Thus, the first decade of dynamic growth of the semiconductor industry was triggered.

Manufacturers worldwide began to integrate these new ICs into a variety of electronic-based products, and a worldwide chain of buyers and sellers to take semiconductors to market was established. Although the industry expanded to a worldwide infrastructure, the United States remained the dominant force in the infrastructure.

During the 1960s, semiconductor devices proliferated with small- and medium-scale integration (SSI, MSI). Logic families, such as the 7400 Series from TI, provided building blocks for electronic equipment and stimulated new electronic equipment designs. The demand for semiconductor memory began to rise in support of the logic building blocks. At the same time, major manufacturing technology advancements led to rapidly increasing device reliability and productivity. By the end of the decade, the industry was well on its way toward $2 billion in annual worldwide sales.

United States' Position in the Infrastructure Begins to Erode

The 1970s was the decade of low-cost electronic products. As the reliability and costs warranted, many companies used ICs to build such products as calculators, watches, or industrial, communications, and data processing equipment.

Early in the 1970s, U.S. companies began to assemble their electronic products overseas to lower costs and expand their markets. European and Japanese markets, in addition to North American markets, became important to U.S. manufacturers.

By the mid-1970s, U.S. manufacturers were moving semiconductor production offshore to take advantage of lower costs and to be closer to the electronic assembly operations that had moved there earlier in the decade.

Metal-oxide semiconductor (MOS) ICs were the dominant products, and by the mid-1970s, large-scale integrated (LSI) devices were proliferating rapidly, further driving the low-cost electronic product era. As a result, worldwide industry sales were nearly $10 billion by 1979.

By the end of the 1970s, the semiconductor business was a worldwide industry with competition on an international scale. The emergence of very large-scale ICs (VLSIs) brought important new products such as microprocessors, read-only memories (ROMs), and erasable programmable ROMs (EPROMs). The age of personal computers and electronic games was born. That age was built on a whole new notion of superlow-cost electronics created by LSI and VLSI semiconductors. The low cost made the items price sensitive and ideal for the low-cost structure of the offshore companies.

In fact, the offshore companies producing semiconductors for U.S. industry were now proving to be capable competitors in all areas of manufacturing, as well as suppliers of low-cost products to the United States. Leadership of the semiconductor infrastructure that the United States had helped to create and had dominated now was being threatened.

Japan and Asia/Pacific Countries Begin to Dominate

Japanese electronic equipment producers seized upon U.S. innovations in the 1970s and, leveraging their indigenous superior productivity, outproduced their U.S. counterparts. Over the last 15 years, the very solution to the fundamental domestic competitive weakness—to move electronic product assembly offshore—has developed these offshore countries (Japan, South Korea, and Taiwan) into fierce domestic and international competitors. In the last half of the 1980s, these competitors now are gaining the dominant share of world markets at all levels of the infrastructure that was built so impressively by the United States such a short time ago. For an example of Japanese dominance, see Figure 2-1. The strengths of Japanese and Asian companies are discussed further in Chapter 5.

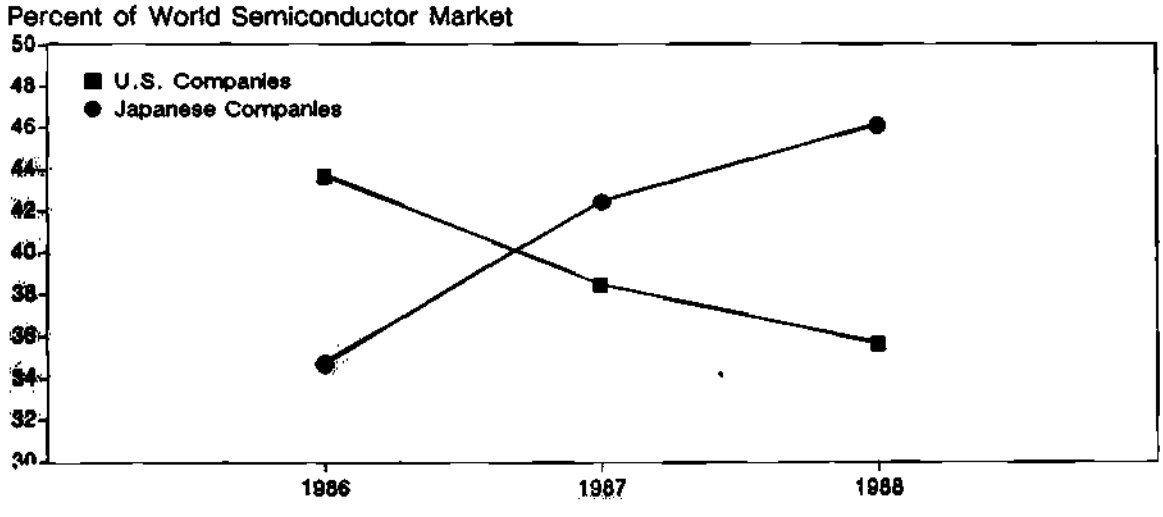
U.S. Electronics Industry Faces a Critical Problem

As a result of losing their competitive edge, U.S. companies are losing worldwide market share at all levels of the infrastructure; the loss now has become self-perpetuating. As the domestic companies lose share, they report declining growth rates and profits. These unfavorable results limit their access to investment capital, which limits the R&D investment available to innovate the requisite new technologies that would regain a leadership position. As this process continues, the U.S. semiconductor manufacturers face the following two-level problem:

- First, the U.S. market for semiconductor devices is shrinking as a percentage of the worldwide semiconductor market (see Chapter 5).

Figure 2-1

U.S. and Japanese Semiconductor Market Shares



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Source: Dataquest
September 1989

- Second, the Japanese and Asia/Pacific countries are gaining share of this shrinking worldwide market at the expense of the U.S. producers' share, while not allowing much increase in U.S. producers' share of their domestic markets.

This decline in competitiveness of the U.S. electronics industry infrastructure is an issue of major concern to Japan, Europe, and other U.S. trading partners for the following two reasons:

- The United States has been the primary source of semiconductor and system innovation since the beginning. Further competitive erosion could stall out that innovation and attract government and/or military interference in the market and/or promulgate adverse trade policies.

- Continued decline in the American electronics industry infrastructure could result in a significant recession of the U.S. economy. Such a recession could eclipse the forecast consumption of a large volume of semiconductors and end products produced by Japanese and Asian manufacturers, leaving them with a severe drop in available market and significant overcapacity.

To sum up the conditions leading to 1989, the United States started the semiconductor industry, developed it into a huge worldwide industry, dominated it for several years, and now is at risk of becoming a minor player in the worldwide electronics market during the last decade of this century.

Electronics Industry Infrastructure: The Waterfall of Demand

The electronic industry infrastructure, of which the semiconductor industry is part, is made up of a complex chain of buyers and sellers working together to satisfy the worldwide demand for electronic products. This complex chain consists of several tiers, beginning with the demand for electronic equipment, continuing to semiconductor devices, and ending with the demand for semiconductor equipment and materials. Demand for various products flows through the buyer/seller chain from one level to the next, producing the cascading waterfall of demand shown in detail in Figure 2-2.

Knowledge of the infrastructure gives insight into how the various industry segments and the economy interact, specifically the following:

- How the demand of one industry segment affects the demand of the next industry segment

- How economic conditions affect the various industry segments

- How technology flows upward from one segment to the next and stimulates demand

The Waterfall Headwaters: Capital Spending

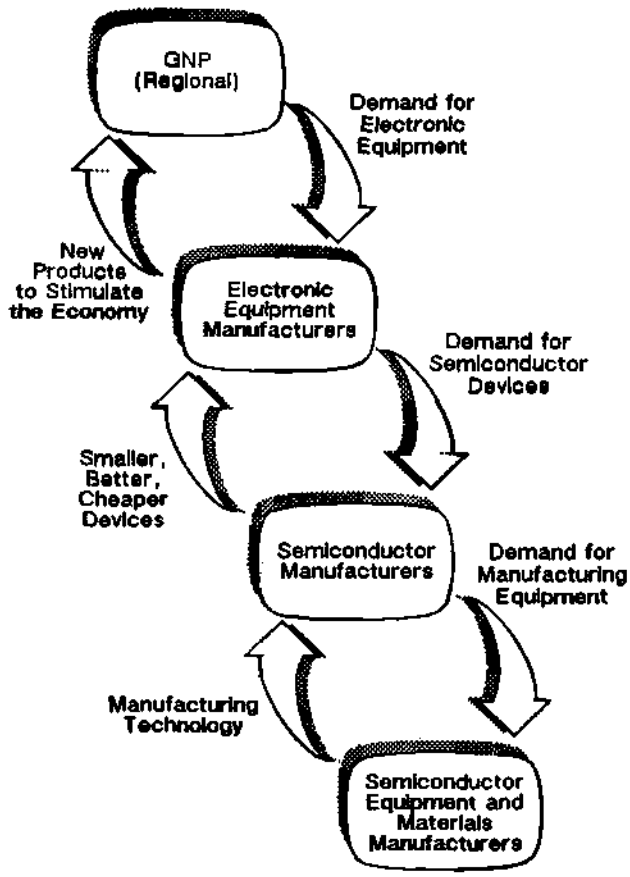
As the worldwide economic climate changes, so does the worldwide demand for electronic equipment. The capital equipment spending sector of each region's economy has the largest influence on a region's demand for electronic products. This concept is developed in Chapter 4. Consumer and government spending have some impact, but to a much lesser degree. It is capital spending that forms the headwaters in the waterfall of demand.

Capital Spending Drives Electronic Equipment

Electronic equipment producers worldwide compete for their share of each region's demand. An equipment producer's ability to compete successfully in its domestic region or to export successfully to fulfill the demand of foreign regions depends largely on the economic climate of its domestic region. Economic factors such as exchange rates against other regions' currencies, relative interest rates, availability within the region of investment capital, and local labor costs determine the productivity and hence the competitiveness of producers located in a given region. The success of domestic producers in gaining share of the home region demand against importing competitors and in supplying foreign regions' demand via export determines the domestic producers' level of electronic equipment production.

Figure 2-2

Waterfall of Demand with Technology Flowing Upstream



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Source: B. Hesley & M. Ford

Electronic Equipment Drives Semiconductor Demand

Electronic equipment production drives semiconductor demand. The supply to this demand can be of semiconductors produced within a local region or imported from other regions. The semiconductor production levels, profits, and resulting available investment capital of semiconductor companies within a region depends on their share of that region's total demand and their ability to export to fulfill demand from other regions. The success of a regional semiconductor manufacturer depends on many factors, but to a large extent, domestic economic conditions and access to foreign regions' demand are the key factors.

Semiconductor Production Drives Semiconductor Equipment

The resulting capital spending by regional semiconductor manufacturers creates the regional available market for the semiconductor equipment industry. Thus demand—driven by the worldwide economic climate and regional economic factors—begins with capital spending and flows down the waterfall until it reaches semiconductor equipment and materials establishing the waterfall of demand.

Technology Flows Upstream

In addition to demand flowing down the waterfall, technology flows upstream, as indicated in

Figure 2-2. Technology provides the impetus for new products.

Manufacturing technology created by the semiconductor equipment manufacturers enables lower cost, lower power, and greater speeds in semiconductor devices. Competition in the semiconductor industry is based in part on manufacturing technology. Competitive attributes such as cost, size, and speed of a semiconductor device is dependent on several manufacturing factors, as follows:

- Yield—how many good devices can be produced in one manufacturing run—affects the costs.
- Integration—how many units of logic and/or memory can be contained in one device—affects both the size and speed of the device.
- Quality and turnaround time—additional factors that depend on manufacturing technology—affect every aspect of competitiveness.

Fundamentally, advances in manufacturing technology create the environment and the tools for continuing advances in semiconductor manufacturing. The productivity and competitiveness of any semiconductor manufacturer is critically dependent on access to state-of-the-art manufacturing equipment, which can come only from an economically and technically strong semiconductor manufacturing equipment industry.

Semiconductor manufacturers combined system design with manufacturing technology and produced semiconductor devices that have greater functionality at lower cost and with better reliability—for example, 32-bit microprocessors, application-specific ICs (ASICs), and 4Mb dynamic random-access memories (DRAMs).

New semiconductor devices allow the creation of new electronic equipment that has new functions, higher performance, and lower cost, and is physically smaller and more portable.

Creative new end systems open new end markets and stimulate end-product demand, thereby stimulating the economy.

Semiconductor Equipment Forms the Base

Figure 2-3 presents the worldwide forecast of electronics equipment production, the semiconductor production required to meet this equipment demand, and the capital spending required of the semiconductor producers to meet this semiconductor demand. Few may realize that 1988 resulted in worldwide electronic equipment production of $760.0 billion, which generated demand for more than $50.5 billion of semiconductor devices, resulting in $18.0 billion spent on semiconductor capital equipment. In other words, the $50.5 billion semiconductor equipment industry is the foundation of the $760.0 billion electronic equipment industry.

Summary

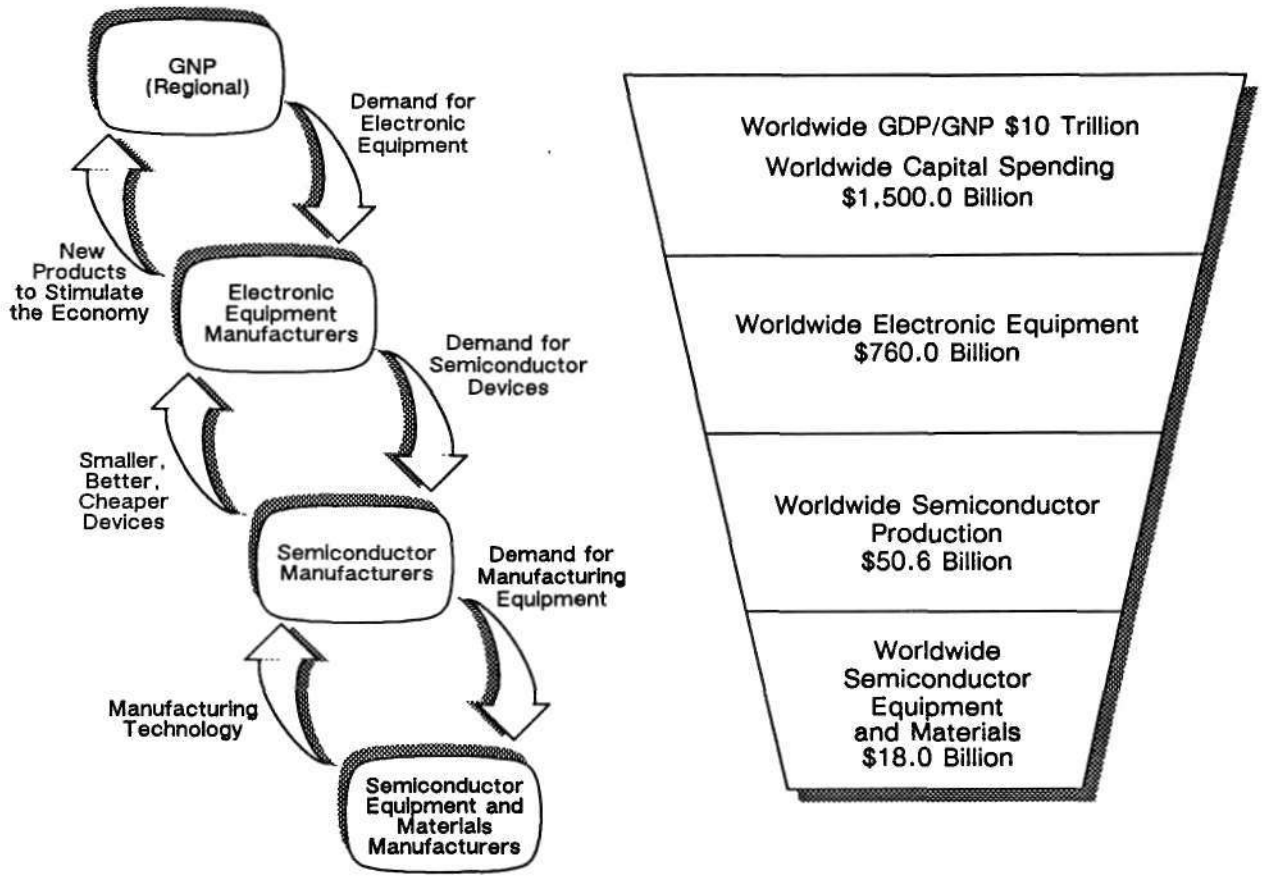
The following points are critical for developing an understanding of the semiconductor industry's future:

- U.S. semiconductor manufacturers are at risk of exiting the stage in a play in which they designed, produced, and acted in the lead role.
- The U.S. economy is dependent on its electronics industry.
  - The electronics industry is dependent on the semiconductor industry.
  - The semiconductor industry is dependent on the semiconductor equipment industry for necessary manufacturing technology.
- The worldwide economy is dependent on the worldwide electronics industry to produce new products to stimulate the worldwide economy.
  - The U.S. electronics industry depends on both the U.S. and worldwide economies.
  - The worldwide electronics industry is dependent on the global economy.

These observations are developed and discussed in succeeding chapters, beginning with global economic conditions and continuing through the production of semiconductor equipment and materials.

Figure 2-3

Base of the Waterfall



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Source: B. Hensley & M. Ford
Dataquest
September 1989

CHAPTER 3

Global Economic Forecast—1989-1990

Introduction

Global and regional economic events influence every level of the electronics industry infrastructure. Some influences are more obvious than others; therefore, understanding the influences of economic events has become necessary for success in such international businesses as the semiconductor industry.

In this chapter, the general global and regional economic conditions that have the most impact on the semiconductor industry are reviewed. This review of economic conditions will accomplish the following:

- Identify critical assumptions about the economy
- Identify the underlying forces that create the demand for electronic equipment
- Provide a forecast of economic conditions for 1989 and 1990

Global and regional economic conditions create the demand for electronic equipment and form the headwaters of the electronic industry demand waterfall. The economic headwaters cascade into succeeding levels of demand, ultimately creating the demand for all products related to the semiconductor industry (see Figure 3-1).

The impact of the economic conditions—in the form of resulting semiconductor industry forecasts—will be identified as each chapter moves down the demand waterfall.

Sources for the Economic Forecast

The *Semiconductor Industry Insights—1990* global and regional economic forecasts are derived from several sources, including individual Dataquest research services, D&B economic forecasts, the U.S. DOC, and the OECD.

Dataquest formulates many of its economic forecasts on the economic forecasts, business surveys, and detailed studies provided by Dun & Bradstreet. Additionally, Dataquest supplies numerous market research services to the computer, computer peripheral equipment, telecommunications, local area networking, and computer software industries in which economic forecasts are maintained. Dataquest research services and forecasts cover all the major free-world regions.

Dun & Bradstreet provides economic forecasts for the United States on a regular basis; these forecasts are incorporated into Dataquest's U.S. economic forecasts.

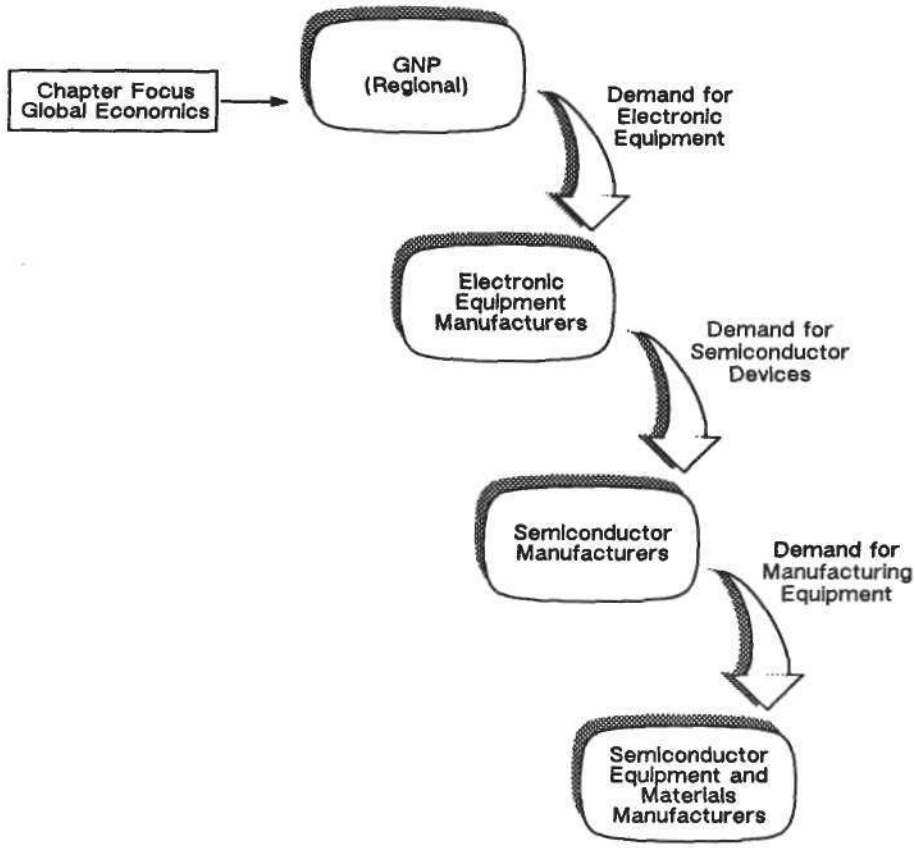
The OECD provides worldwide economic forecasts on a regular basis under a charter of the United Nations to stimulate economic growth worldwide. The OECD has published economic forecasts since the charter was signed in Paris in 1960 to promote policies designed to do the following:

- Achieve the highest sustainable worldwide economic growth and employment, while maintaining financial stability
- Contribute to sound economic expansion in both member and nonmember countries
- Contribute to the expansion of worldwide trade on a multilateral nondiscriminatory basis

The *OECD Economic Outlook* is based largely on the work of the Department of Economy and Statistics within the OECD and is based on both analysis and economic data provided by the member countries.

Figure 3-1

Waterfall of Demand



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Source: B. Hesley & M. Ford

Historical Perspective: Events of Global and U.S. Economies through 1988

Global Economy—Year-End 1988

The worldwide economic climate appeared healthier at year-end 1988 than at any time since the early 1970s. As reported by the OECD in the December 1988 *OECD Economic Outlook*, total output for the OECD member nations was growing at an annual rate of more than 4.0 percent from mid-1987, as opposed to an historical growth rate of less than 3.5 percent over the preceding 15 years, as shown in Table 3-1. As Table 3-1 indicates, the jump in output growth has been quite well balanced between the United States, Japan, and the major European countries.

As Table 3-2 shows, the primary driving force for growth of OECD countries' output has been private nonresidential investment (capital spending to increase manufacturing productivity and capacity), which increased 11 percent in 1988 over 1987 across all OECD countries. Inflation was well managed and in spite of such healthy growth, increased only slightly in 1987 and 1988 over 1986 levels. Annual inflation was held to 4 percent in 1988 across all OECD nations, compared with more than twice that figure in the period from 1974 through 1982 (see Table 3-1). This unusually healthy climate reflects the confluence of a number of global factors, including the following:

- Several years of close international economic cooperation and accommodating monetary policies
- The impact of the 1986 reduction in oil prices

Table 3-1

Key Worldwide Macroeconomic Developments
OECD Member Nations

% Change from Previous Period	Average 1974-79	Average 1980-82	Average 1983-86	1987 H1	1987 H2	1988 H1	1988 H2
Real GNP/GDP							
United States	2.6%	(0.3%)	4.1%	3.9%	5.0%	4.0%	2.5%
Japan	3.6%	3.7%	3.9%	3.8%	6.0%	6.1%	4.5%
Four Major European Countries	2.3%	0.7%	2.3%	1.9%	4.1%	3.5%	3.8%
OECD Europe (13 Countries)	2.3%	0.8%	2.4%	2.2%	3.6%	3.5%	3.8%
Total OECD	2.7%	0.8%	3.4%	3.2%	4.6%	4.1%	3.3%
Total Employment							
United States	2.5%	0.2%	2.4%	2.7%	2.6%	2.2%	2.0%
Japan	0.7%	1.0%	0.9%	0.7%	1.8%	1.9%	1.3%
Four Major European Countries	0.2%	(0.5%)	0.4%	0.7%	0.9%	1.0%	1.0%
OECD Europe (13 Countries)	0.3%	(0.4%)	0.5%	1.0%	1.1%	1.1%	1.0%
Total OECD	1.1%	0.1%	1.2%	1.6%	1.8%	1.8%	1.5%
Productivity							
United States	0	(0.5%)	1.6%	1.1%	2.3%	1.7%	0.5%
Japan	2.9%	2.7%	2.9%	3.1%	4.2%	4.1%	3.3%
Four Major European Countries	2.1%	1.2%	1.9%	1.2%	3.1%	2.4%	2.8%
OECD Europe (13 Countries)	2.0%	1.2%	1.9%	1.1%	2.5%	2.4%	2.8%
Total OECD	1.5%	0.6%	2.2%	1.6%	2.7%	2.3%	1.8%
Inflation (GNP Deflator)							
United States	8.0%	8.4%	3.3%	3.2%	3.0%	2.9%	4.0%
Japan	8.0%	2.9%	1.3%	(1.1%)	1.0%	(0.2%)	0.8%
Four Major European Countries	11.4%	10.9%	5.8%	3.3%	3.5%	3.6%	3.5%
OECD Europe (13 Countries)	11.7%	11.4%	6.7%	4.1%	4.4%	4.7%	4.8%
Total OECD	9.6%	9.0%	4.5%	3.2%	3.4%	3.4%	4.0%
Current Balance ($B)							
United States	(1.1)	0	102.1	(156.9)	(151.0)	(140.6)	(124.0)
Japan	2.8	0.3	47.7	91.7	82.4	80.0	77.0
Four Major European Countries	3.9	(10.0)	19.6	48.0	21.4	20.5	3.0
OECD Europe (13 Countries)	(5.5)	(29.2)	25.0	53.7	18.3	16.9	4.0
Total OECD	(11.2)	(38.4)	(40.2)	(28.7)	(69.6)	(59.7)	(61.0)

Source: 1988 OECD Economic Outlook

- Dynamic improvement in U.S. competitiveness in world markets driven by the sharply lower value of the dollar, which resulted in an export boom that has significantly reduced the U.S. trade deficit
- Stable financial and currency exchange market conditions reflecting a stable dollar over most of 1988
- Improvement in the confidence level by both consumers and enterprises in global economic stability, which resulted in:
  - Continued moderation of inflation
  - The assurance of continued private capital flow to fund the huge U.S. external account deficit
- Continued gradual increase in wages, appropriately offset by increasing productivity in order to sustain increasing consumption and investment without eroding corporate profits and without increasing inflation
- Increasing worldwide corporate profits

Table 3-2

Contributions to Changes in Real GNP/GDP
OECD Member Nations

	Percent Real GNP/GDP in Previous Period				
	Average 1974-1979	Average 1980-1982	Average 1983-1986	1987	1988
United States					
Total Domestic Demand	2.4%	(0.5%)	5.4%	3.1%	3.0%
Private Consumption	1.8%	0.5%	3.0%	1.8%	1.8%
Capital Spending	0.4%	(0.2%)	0.5%	0.3%	1.0%
Change in Foreign Balance	0.2%	0.2%	(1.2%)	0.2%	0.8%
Real GNP/GDP	2.6%	0.3%	4.1%	3.4%	3.8%
Japan					
Total Domestic Demand	3.2%	1.9%	3.3%	5.0%	7.5%
Private Consumption	2.4%	1.3%	1.7%	2.2%	2.8%
Capital Spending	0.1%	0.8%	1.4%	1.5%	3.3%
Change in Foreign Balance	0.4%	1.7%	0.6%	(0.7%)	(1.8%)
Real GNP/GDP	3.6%	3.7%	3.9%	4.3%	5.8%
Four Major European Countries					
Total Domestic Demand	2.0%	0.2%	2.2%	3.7%	4.3%
Private Consumption	1.5%	0.6%	1.4%	2.3%	2.3%
Capital Spending	0.1%	(0.1%)	0.4%	0.7%	1.0%
Change in Foreign Balance	0.3%	0.5%	0	(1.1%)	(1.0%)
Real GNP/GDP	2.3%	0.7%	2.2%	2.8%	3.8%
OECD Europe					
Total Domestic Demand	2.1%	0.2%	2.3%	3.6%	4.0%
Private Consumption	1.5%	0.5%	1.4%	2.1%	2.0%
Capital Spending	0.1%	(0.1%)	0.4%	0.7%	1.0%
Change in Foreign Balance	0.2%	0.6%	0	(1.0%)	(0.8%)
Real GNP/GDP	2.4%	0.8%	2.3%	2.8%	3.5%
Total OECD					
Total Domestic Demand	2.4%	0.2%	3.8%	3.6%	4.0%
Private Consumption	1.8%	0.6%	2.1%	2.0%	2.0%
Capital Spending	0.2%	0	0.6%	0.7%	1.5%
Change in Foreign Balance	0.2%	0.6%	(0.4%)	(0.4%)	(0.3%)
Real GNP/GDP	2.7%	0.8%	3.4%	3.3%	4.0%
% Change Previous Year					
Total OECD					
Total Domestic Demand	2.4%	0.2%	3.8%	3.6%	4.0%
Private Consumption	3.0%	1.0%	3.5%	3.2%	3.3%
Capital Spending	2.3%	(0.1%)	4.8%	5.1%	11.3%

Source: 1988 OECD Economic Outlook

In spite of this relatively rosy picture, there are reasons to be concerned about the future health of the global economy. The critical global factor is the availability of private capital to fund U.S. deficits. The continued availability of private capital depends on the perceived stability of the dollar. The stability of the dollar in turn depends on the perceived noninflationary growth potential of the U.S. economy and continued reduction of the external trade deficit through growth of U.S. exports.

Because the United States makes up nearly one-half of the world's GNP and the continued health of the world's economy depends on the health of the United States, it is important to review the key factors that have shaped the U.S. economy over the past two decades.

Development of U.S. Economy—1970 through 1988

The period between 1970 and 1982 was beset with cyclical periods of high inflation followed by strong measures from the Federal Reserve Board to squelch the inflation. The primary cause of inflation was the lack of capital investment funding necessary to increase productivity.

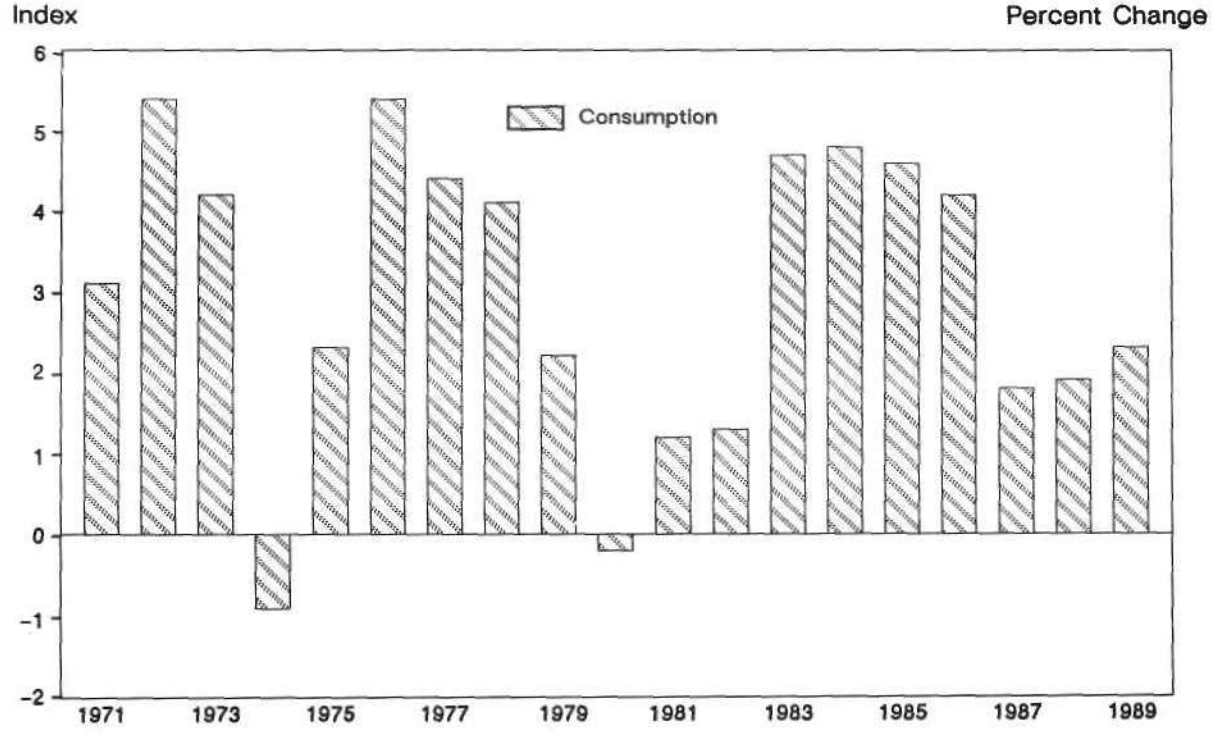
The result was significant instability in the U.S. economy manifesting itself as recessions in 1970, 1974, 1980, and 1982, as Figure 3-2 shows. The instability of the U.S. economy and its swings from expansion to recession were felt in Europe as well.

Japan Distances Itself from U.S. Economic Swings

However, since the 1974 recession, Japan managed to insulate itself from both the recessions and inflation. Japan was able to maintain solid, stable growth since 1975, as Table 3-1 shows. During the period starting in 1974, Japan developed a production capacity and productivity level that made it extremely competitive in the world market for most manufactured goods. As a result, by the late 1970s, much of the traditional U.S. industrial production shifted to the more productive, more competitive Japanese. This shift further exacerbated U.S. economic instability.

Figure 3-2

U.S. Consumer Consumption



0004672-9

Source: University of Michigan Consumer Survey

Reagan Seeks to End Instability

To end this instability and squelch inflation once and for all, U.S. President Ronald Reagan instituted his supply-side economic concept in the form of a tax cut in 1981. The idea behind this tax cut was to expand the disposable income for consumers by cutting personal income taxes. The increase in disposable income was intended to increase domestic consumption and domestic savings. This would expand the supply of investment funds while also increasing domestic demand for products and services. The increased domestic demand would increase domestic output. Increased domestic output would then increase the tax base, which in turn would more than make up the lost revenue from the tax cut.

Results of the Supply-Side Concept

History shows that the idea of supply-side economics partially worked. Consumption soared, and the buying spree was on! But the ratio of savings to disposable income fell from 7.5 percent in 1981 to 3.6 percent by 1987. (Consumption patterns are illustrated by Figure 3-2; savings patterns are shown in Table 3-5.)

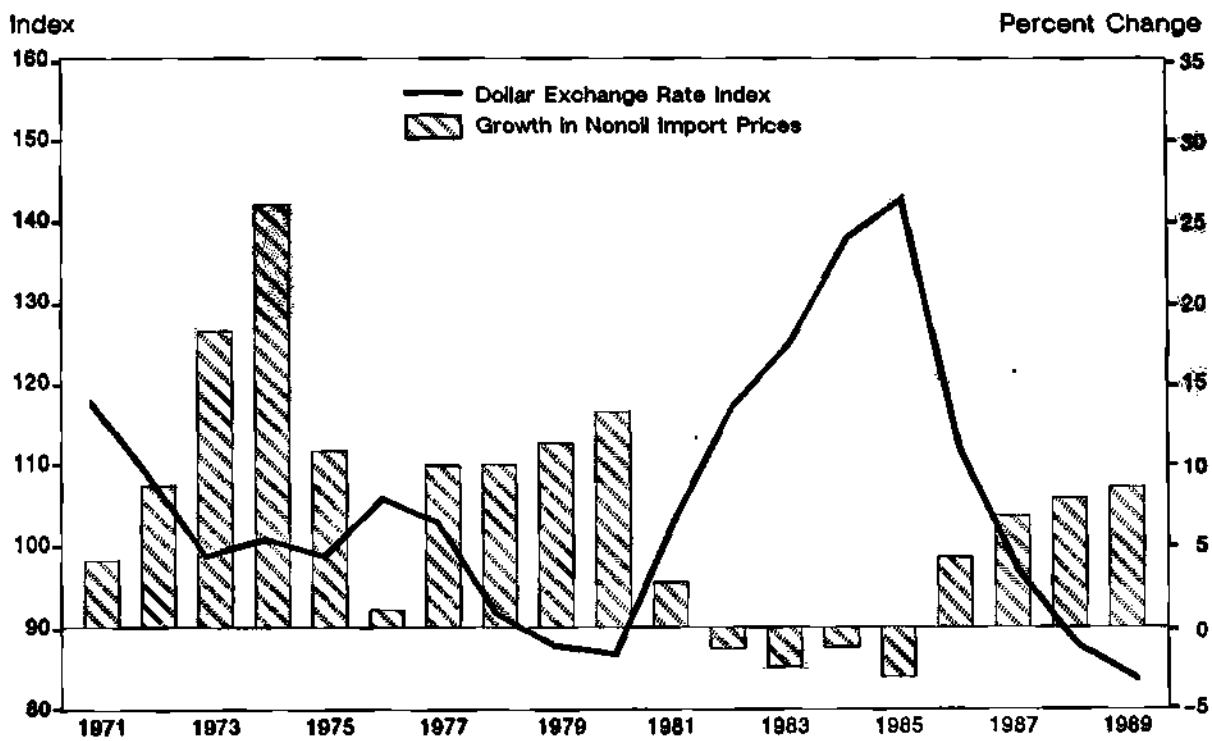
Furthermore, the benefactors of all this consumption were not the domestic producers, as intended, and the tax cut was not accompanied by an appropriate government spending cut. Thus, a large and growing federal budget deficit quickly resulted.

Foreign investors eagerly sought to fund this growing federal debt and profit from the high rates of return offered in the United States. As a result of demand for the U.S. dollar, the value of the dollar was pushed up 50 percent between 1981 and 1985.

The high dollar value shown in Figure 3-3 made imports (largely from Japan) less expensive than domestic goods. Therefore, both Japanese and European producers reaped the benefits of the tax cuts at the expense of domestic suppliers. The expected increased output from domestic producers failed to materialize; therefore, the tax base was not increased, and the federal deficit continued to swell (see Figure 3-4).

Figure 3-3

Imported Inflation and the Dollar

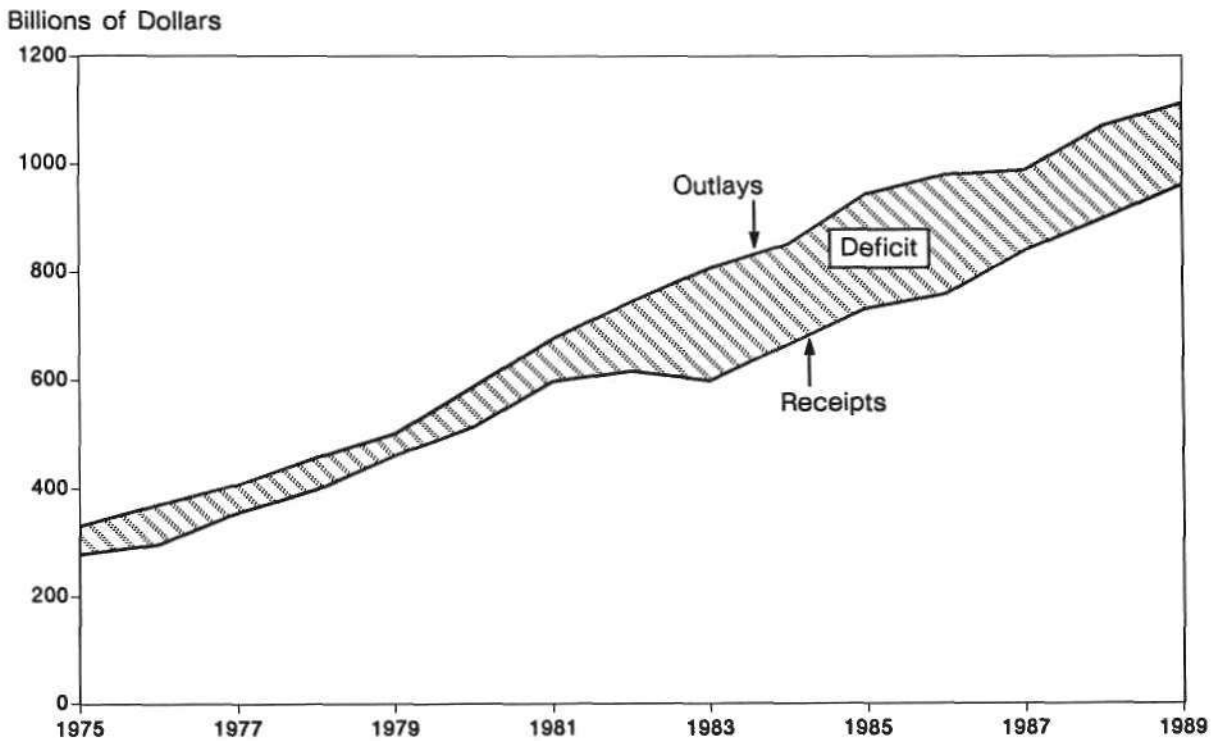


0004672-10

Source: U.S. Department of Commerce
Federal Reserve Board
Dun & Bradstreet

Figure 3-4

Federal Budget Receipts and Outlays—1975 through 1989



0004672-11

Source: U.S. Office of Management and Budget
Dataquest
September 1989

In effect, the supply-side economic concept halted the historical inflation-recession cycles that previously had resulted from poor domestic productivity, wage-price spirals, and absence of adequate sources of investment capital. The reason these cycles halted is that an increasing share of the domestic market was being supplied by foreign suppliers such as Japan, which had the productivity and import price benefits to keep consumer prices low and thus hold down inflation (see Figure 3-5).

Trade Imbalances Occur

The influx of low-cost goods held down inflation but created problems for U.S. producers—the loss of market share in their domestic market and the inability to compete in the world markets because of the high dollar. The result was that the United States developed a severe trade imbalance, creating a deficit of more than $100 billion annually in its external account from 1983 through 1986. This deficit required more and more foreign investment capital.

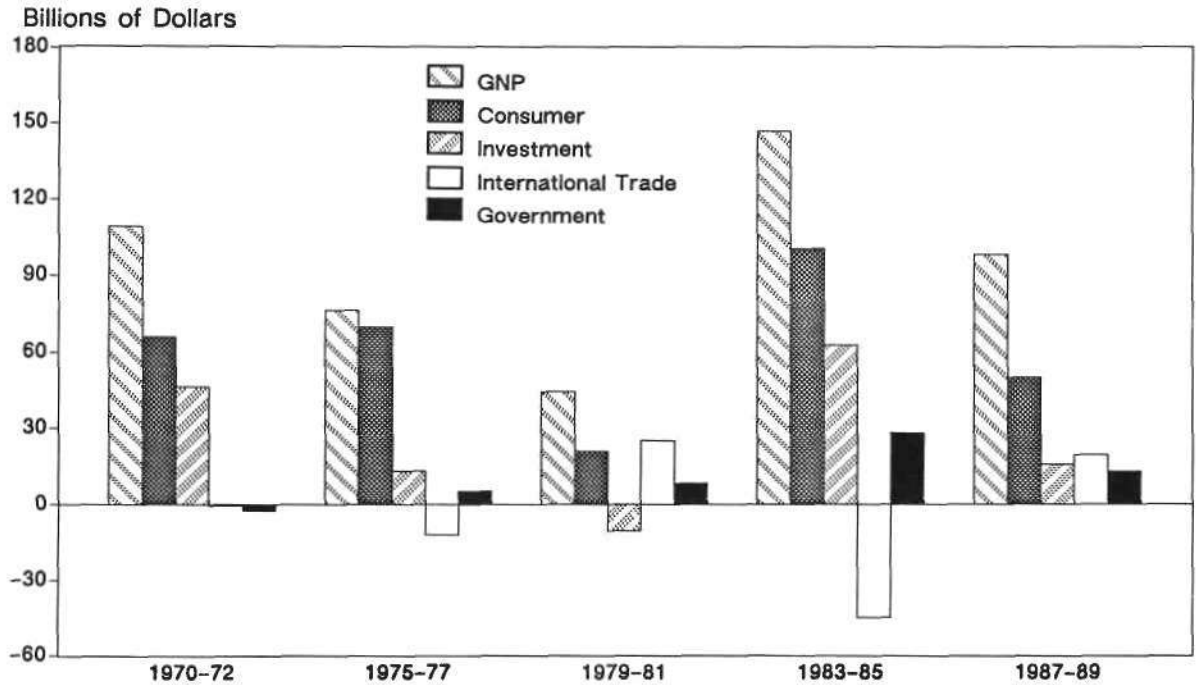
Meanwhile, Japan was developing a huge export-driven external account surplus of nearly $50 billion annually; the four major European countries developed a similar $20 billion annual surplus (see Table 3-1).

G-7 Countries Formulate Plan to Adjust U.S. Deficit

Such widening external trade imbalances created global fears of massive monetary instability. Early in 1985, responding to fears of instability, the finance ministers of the G-7 countries (United States, United Kingdom, France, Germany, Italy, Japan, and Canada) formulated a plan to manipulate the value of the dollar to a significantly lower level. The plan would allow the United States to be more competitive in Europe while discouraging U.S. consumption of then higher-priced imports. The G-7 countries also instituted fiscal and monetary policies within their own countries to stimulate spending in order to create world market growth for U.S. exports to aid the United States in the trade balance crisis.

Figure 3-5

Components of U.S. Real GNP Growth—1970-1989



Base: 1982 U.S. dollars
Values are average annual amounts of change.

0004672-12

Source: U.S. Department of Commerce
Dun & Bradstreet

Since 1985, the United States has increased its capital spending to improve productivity, managed its labor rates to avoid inflation, and—once the oil prices were reduced in 1986—systematically increased its output and export while slowly reducing imports.

Because of the actions taken by G-7 countries and various actions taken by the United States, the following results occurred:

- The value of the dollar fell 50.0 percent from the March 1985 level to that of year-end 1987.
- The huge U.S. external account deficit was reduced 25.0 percent to $120.0 billion.
- U.S. exports increased.

The goals of G-7 countries were starting to be accomplished, albeit slowly, as illustrated in Figures 3-6 through 3-8.

However, at this date, the United States still has not accomplished the prudent fiscal policy of a balanced federal budget. Thus, the demand remains for a huge supply of foreign funds to finance both the federal and trade deficits. Given this demand, the Federal Reserve has limited ability to apply traditional interest rate controls when inflationary pressures arise. This sets up a fear that inflation can once again become a dominant theme within the United States and, therefore, the world. Such fears tend to amplify monthly trends reported within the United States regarding both trade and inflation, and tend to create fear-driven variations in the value of the dollar.

New Threats to U.S. Economy

Meanwhile, as the United States and its major trading partners presently are enjoying strong growth within an acceptable range of inflation, U.S. companies are under increasing competitive pressure from the newly industrialized countries

(NICs) such as Taiwan, South Korea, Singapore, Hong Kong, and India in both the U.S. domestic market and in Europe. Additionally, access to the expanding NIC and Japanese import markets is restricted largely to U.S. companies. The same potential for restricted access by U.S. companies will exist in Europe after 1992.

For the U.S. to continue the healthy growth that it enjoyed during the past two years—on which the health of the global economy depends—the United States has a critical need to achieve the following:

- Gain a reasonable share of the emerging NIC markets
- Increase its share in the Japanese market
- Maintain and increase its share of the European market

Global and Regional Economic Forecast—1989 and 1990

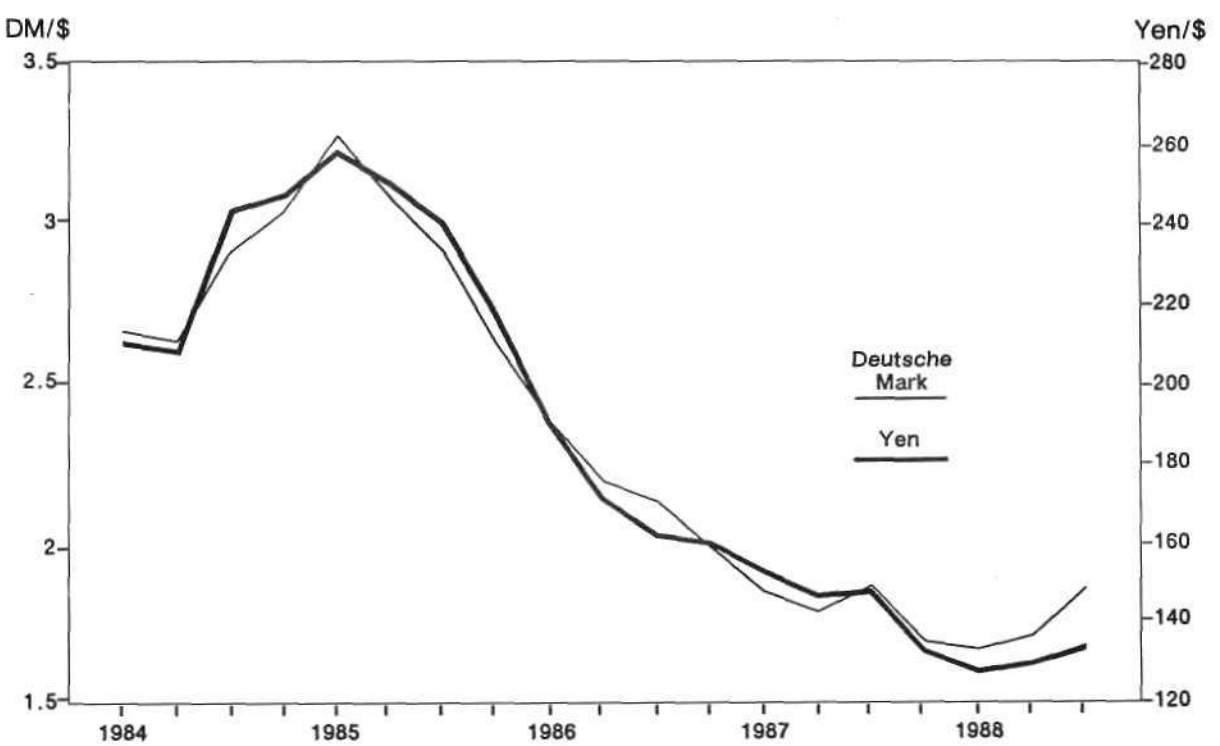
Introduction—The Global View

The global economic climate appeared healthy at year-end 1988, but this good health did not exclude some vulnerabilities. As 1989 progresses, significant risks and uncertainties regarding future events could upset this apparent future health. These risks include the following:

- Potential for higher-than-anticipated growth rates further reducing unemployment and thereby igniting an inflationary wage-price spiral (This is especially worrisome in the United States, the United Kingdom, and Canada.)

Figure 3-6

Dollar Exchange Rates—1984 through 1988
(Quarterly Averages)

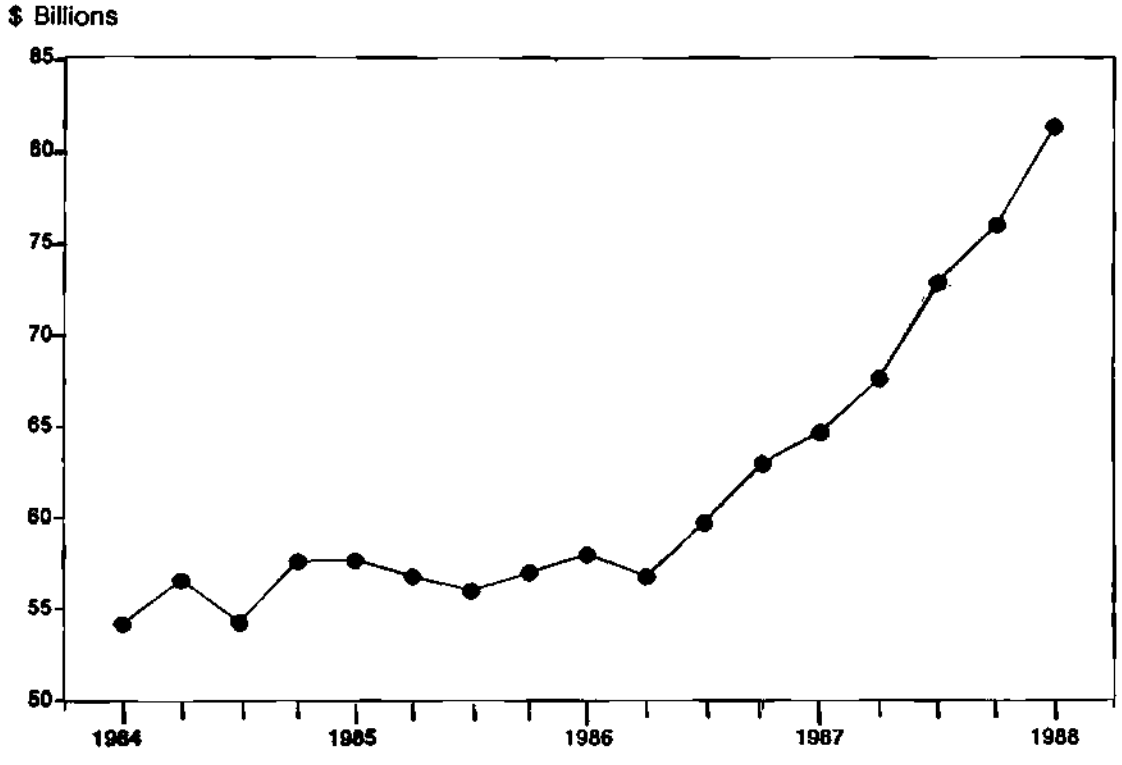


0004672-13

Source: U.S. Department of Commerce

Figure 3-7

U.S. Merchandise Exports—1984 through 1988
(Quarterly Averages)



Note: Based on 1982 dollars.
0004672-14

Source: U.S. Department of Commerce

- Continuing uncertainties about the extent and timing of further orderly reduction in the large external account imbalances of the United States, Japan, Germany, and the United Kingdom

- Risk of ineffective fiscal restraint, particularly in the United States, continuing to build government budget deficits

- Loss of confidence in the U.S. dollar by exchange and monetary markets resulting in a sharp and cumulative decline

The overall OECD forecast for 1989 and 1990 as presented in the December 1988 *OECD Economic Outlook* is given in Table 3-3 and assumes that the aforementioned risks will be avoided. The major points that can be identified in the table are discussed in the following paragraphs.

The current dynamic growth in GNP/GDP is forecast to ease to a more reasonable 2.8 percent in 1990, down from the 1988 level of 4.0 percent. However, annual growth in consumer demand is projected to decline slightly to 2.8 percent in 1990 from the 3.3 percent 1988 level after adjusting to the recent credit liberalization policies in many of the OECD countries. Savings ratios are expected to level off, except possibly in Japan.

Capital spending growth is expected to drop from the 11.3 percent peak in 1988 to less than one-half that rate—4.8 percent—by 1990. This reduction is based on the very high capital investment/output ratios prevalent in most OECD countries in 1988, coupled with the reduced output growth forecast.

Unemployment is forecast to remain constant at 7.5 percent across all the OECD countries, with Europe holding at slightly more than 10.0 percent and the United States at slightly more than 5.0 percent. At the forecast level of output growth, wages should grow less rapidly than productivity, thus assuring inflation-free growth.

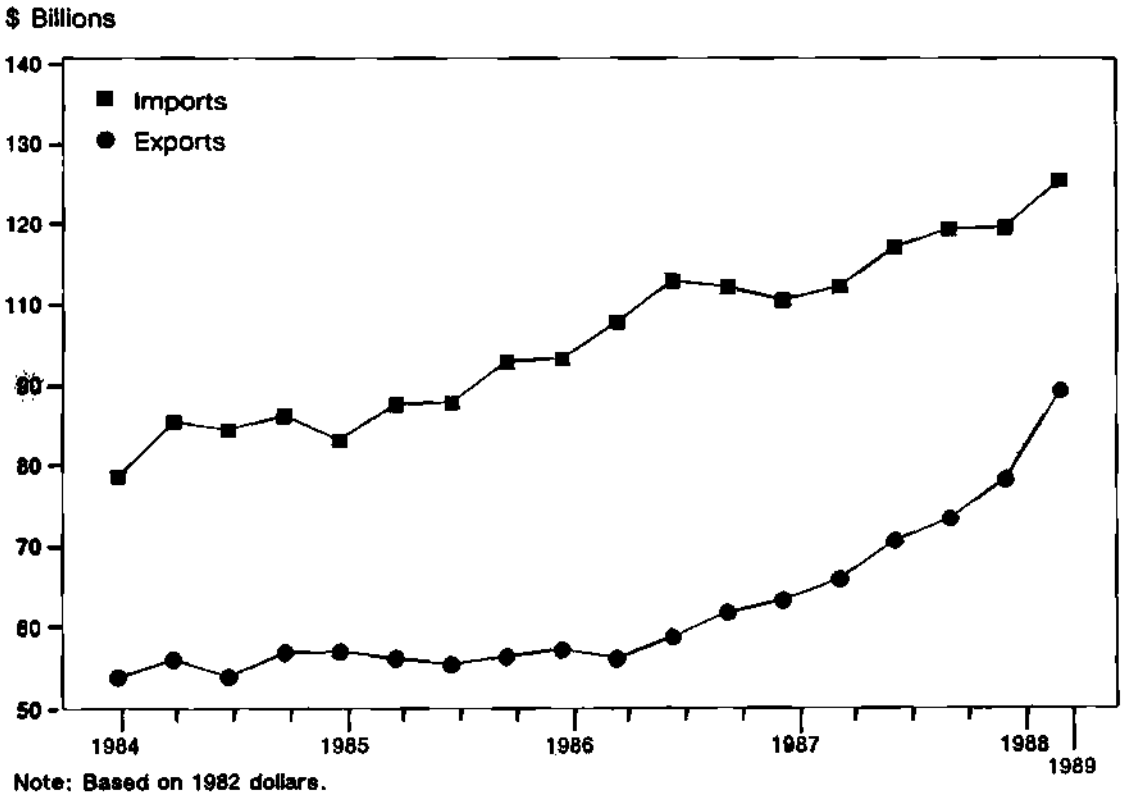
The GNP price deflator measurement of inflation across all the OECD countries is forecast to creep up slowly from 3.5 percent in 1988 to 4.0 percent in 1990, primarily driven by mild inflationary pressures from the United States and the United Kingdom. Should growth within these countries increase more rapidly than forecast, some interest rate increases could choke off inflationary pressure.

The projected pattern of regional demand is expected to continue to support the gradual external adjustment of the real trade imbalances of the United States and Japan. Thus, the current U.S. account deficit should fall to slightly more than $100 billion or to 2 percent of 1990 GNP in 1990, compared with almost 3 percent in 1987. Japan's surplus is expected to decline gradually to $70 billion by 1990.

Confidence in the U.S. dollar will be maintained, thus allowing a slight increase in the value of the dollar over year-end 1988 levels throughout the forecast period.

Figure 3-8

Merchandise Imports and Exports—1984 through 1989



Note: Based on 1982 dollars.

0004672-15

Source: U.S. Department of Commerce

Table 3-3

Total OECD Economic History and Outlook—1988 through 1990

Contributions to Change in Real GNP/GDP	1983-1986 Average	1988	1989	1990
Real GNP/GDP (Percentage of Real GNP/GDP in Previous Period)	3.4%	4.0%	3.3%	2.8%
Total Domestic Demand	3.8%	4.0%	3.3%	2.8%
Private Consumption	2.1%	2.0%	2.0%	1.8%
Private Nonresidential Investment	0.6%	1.5%	1.0%	0.8%
Change in Foreign Balance	(0.4%)	(0.3%)	0	0
Year-to-Year Growth in Real GNP/GDP (Percentage Change SAAR* from Previous Period)				
Total Domestic Demand	3.8%	4.0%	3.3%	2.8%
Private Consumption	3.5%	3.3%	3.0%	2.8%
Private Nonresidential Fixed Investment	4.8%	11.3%	7.0%	4.8%
Inflation (Percentage Change SAAR* from Previous Period)				
Total OECD	4.5%	3.5%	4.0%	4.0%
United States	3.3%	3.3%	4.5%	4.8%
Japan	1.3%	0.3%	1.0%	1.5%
OECD Europe	6.7%	4.8%	4.8%	4.3%
Unemployment (Percent of Labor Force)				
Total OECD	8.0%	7.3%	7.3%	7.5%
United States	7.5%	5.5%	5.5%	5.5%
Japan	2.6%	2.5%	2.5%	2.5%
OECD Europe	10.3%	10.3%	10.3%	10.3%
SAAR	**1987**			
Current Balances (Billions of Dollars)				
Total OECD	($49.0)	($61.0)	($50.0)	($51.0)
United States	($154.0)	($132.0)	($116.0)	($108.0)
Japan	$87.0	$79.0	$77.0	$72.0
Germany	$44.9	$45.0	$51.0	$52.0
OECD Europe	$36.0	$11.0	$9.0	$7.0
NICs	$31.0	$22.0	$17.0	$14.0

*SAAR = Seasonally Adjusted Annual Rate

Source: 1988 OECD Economic Outlook

U.S. Economic Forecast—1989 and 1990

Background

The United States enjoyed a vigorous 1988 with real GNP growth of nearly 4.0 percent, as shown in Table 3-4. This growth was driven primarily by the two following forces:

- Double-digit quarterly increases in private business capital spending for durable goods over the first half of 1988
- Strong exports of manufactured goods—especially chemicals, primary metals, computers, and office equipment

The export trade gains that started in mid-1987 continued throughout most of 1988 and pushed capacity utilization rates to very high levels (87 percent), thus escalating demand for both manufacturing and automation equipment and labor. This triggered considerable fear of wage-price-spiraling inflation and caused the Federal Reserve Board to exercise restraint in economic growth by pushing up the rediscount rate several times throughout the year. Consequently, short-term interest rates ended the year at 6.7 percent.

Such prompt restraint by the Federal Reserve reduced inflationary fears within the international monetary and exchange markets and allowed sufficient capital inflow with increases in long-term interest rates. Long-term rates remained below 9 percent, and the dollar actually appreciated nearly 7 percent from its year-end 1987 level through mid-October. Late in 1988, publication of third-quarter trade figures and increased price growth created some loss of confidence, and the dollar fell back to its 1987 level while long-term interest climbed to more than 9 percent by the end of the year.

As a result of a continuing high demand for labor, the United States experienced high levels of employment in 1987, which in turn generated strong growth (2.8 percent) in consumer spending. Consumer savings ratios also increased slightly from the 3.5 percent low in 1987 to more than 4.0 percent by the end of 1988. However, the decline of unemployment to 5.1 percent early in 1989 rekindled fears that the Federal Reserve would apply further monetary restraints and that the economy would overreact and go into a recession before the end of 1989. As 1989 has progressed, these fears have abated somewhat after first-half indicators showed signs that the economy was slowing itself a bit, primarily due to the impact of these fears of recession and of higher short-term interest rates on consumer spending.

For 1989 and 1990, Dataquest and Dun & Bradstreet forecast slower growth, as seen in Table 3-4 and Figure 3-9, but not a recession. This slower growth will begin in the third quarter of 1989 and extend through 1990. Real GNP growth should slow from 1988's estimated 3.9 percent to 3.0 percent in 1989 and 1.7 percent in 1990 before recovering with a healthy 4.0 percent growth in 1991.

As 1989 continues, the U.S. economy remains very volatile and sensitive to the interaction between the following key factors:

- Government fiscal policy regarding the federal budget deficit
- Monetary policies and related interest rates
- Continued improvement in the balance of trade
- Consumer spending
- Capital spending

D&B's forecast is explained in terms of the critical factors shown in Table 3-4 and in the sections that follow.

Government Fiscal Policy

The fiscal 1989 budget is, with few exceptions, a clone of the previous year's budget. In the 1990 budget, the Bush administration will stress spending cuts rather than increased taxes, with the exception of new "user fees," excise taxes, and already legislated tax increases. As a result, the fiscal 1990 budget will specify negligible real growth in defense and nondefense federal spending.

Interest Rates and Monetary Policy

By recently raising the discount rate to 7 percent, the Federal Reserve Board has continued to demonstrate its determination to restrain inflation. This tight money policy has created a situation where some short-term rates are higher than long-term rates. Experience shows that this inverted yield curve is a precursor of slower economic growth or even a recession. The Federal Reserve Board will maintain this severe antiinflation policy until it is satisfied that the inflation risk has diminished or that a recession is on the horizon. Long-term rates are forecast to exceed 10 percent for the three quarters to mid-1990 and then fall back to more traditional levels, facilitating the 1991 expansion.

Table 3-4

U.S. Economic History and Outlook—1988 through 1990
(Billions of 1982 Dollars)

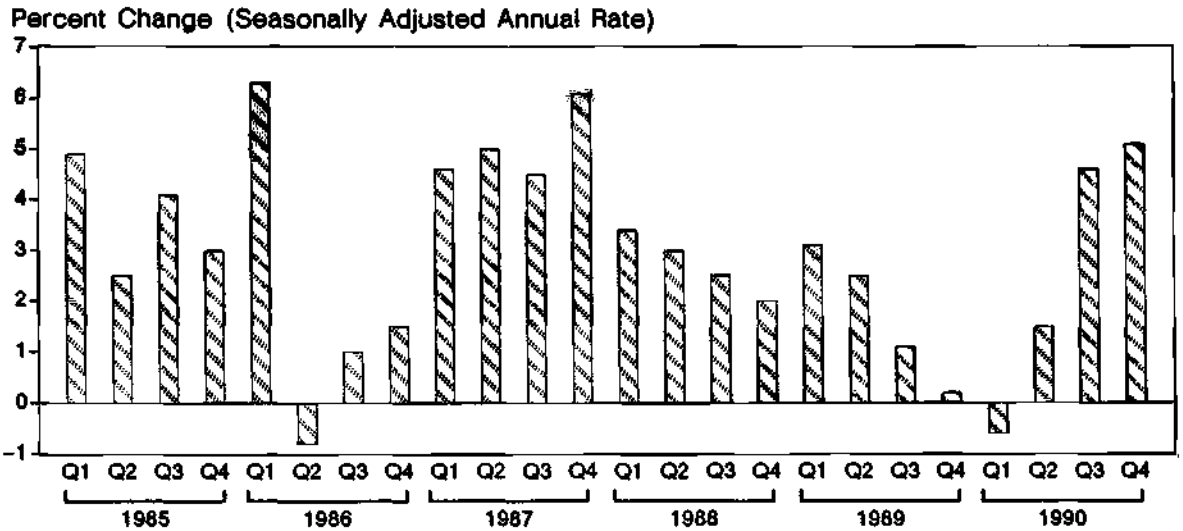
					1989				1990			
	1988	1989	1990	1991	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Real GNP	$3,996.0	$4,114.3	$4,183.2	$4,351.7	$4,083.5	$4,114.5	$4,126.6	$4,132.5	$4,126.8	$4,152.0	$4,198.7	$4,255.1
% Change Previous Year	3.9%	3.0%	1.7%	4.0%								
% Change SAAR*					5.1%	3.1%	1.2%	0.6%	(0.6%)	2.5%	4.6%	5.5%
Consumption	$2,592.2	$2,667.3	$2,732.2	$2,828.9	$2,639.2	$2,660.1	$2,678.2	$2,691.5	$2,703.2	$2,719.9	$2,740.1	$2,765.4
% Change Previous Year	2.8%	2.9%	2.4%	3.5%								
% Change SAAR*					2.0%	3.2%	2.7%	2.0%	1.8%	2.5%	3.0%	3.7%
Private Fixed Investment	$ 487.5	$ 514.1	$ 531.6	$ 563.4	$ 503.2	$ 512.4	$ 518.7	$ 521.9	$ 521.9	$ 525.8	$ 533.5	$ 545.1
% Change Previous Year	9.5%	5.5%	3.4%	6.0%								
% Change SAAR*					10.0%	7.5%	5.0%	2.5%	0	3.0%	6.0%	9.0%
Fixed Investment Equip.	$ 362.4	$ 386.1	$ 405.8	$ 439.0	$ 374.1	$ 384.3	$ 391.3	$ 394.7	$ 395.1	$ 399.6	$ 408.0	$ 420.4
% Change Previous Year	13.4%	6.5%	5.1%	8.2%								
% Change SAAR*					9.3%	11.4%	7.5%	3.5%	0.4%	4.6%	8.7%	12.7%
Residential Investment	$ 191.8	$ 200.3	$ 205.0	$ 216.3	$ 200.2	$ 202.9	$ 206.7	$ 210.2	$ 213.1	$ 215.2	$ 217.3	$ 219.6
% Change Previous Year	(1.7%)	4.4%	2.3%	5.5%								
% Change SAAR*					1.6%	5.5%	7.7%	6.9%	5.6%	4.0%	4.0%	4.3%
Inventory Accumulation	$ 42.0	$ 26.0	($ 5.0)	$ 15.0	$ 39.0	$ 35.0	$ 23.0	$7.0	($ 6.0)	($ 8.0)	($ 7.0)	0
Government Purchases	$ 782.3	$ 801.8	$ 806.4	$ 813.5	$ 798.6	$ 799.2	$ 801.2	$ 808.2	$ 801.3	$ 803.5	$ 807.9	$ 812.9
% Change Previous Year	0.3%	2.5%	0.6%	0.9%								
% Change SAAR*					1.6%	0.3%	1.0%	3.5%	(3.4%)	1.1%	2.2%	2.5%
Net Exports	($ 100.2)	($ 95.2)	($ 86.8)	($ 75.5)	($ 97.8)	($ 93.1)	($ 94.5)	($ 95.4)	($ 93.5)	($ 92.1)	($ 82.9)	($ 78.9)
GNP Deflator $117.7	$ 121.7	$ 128.0	$ 134.3	$ 140.1	$ 125.5	$ 127.2	$ 128.9	$ 130.5	$ 132.2	$ 133.7	$ 135.1	$136.4
% Change Previous Year	3.4%	5.2%	4.9%	4.3%								
% Change SAAR*					5.0%	5.5%	5.5%	5.1%	5.3%	4.6%	4.3%	3.9%
Interest Rates												
3-Month T-Bill	6.7%	9.3%	8.9%	8.0%	8.5%	9.1%	9.6%	9.8%	9.5%	9.1%	8.7%	8.4%
30-Year T-Bond	9.0%	9.6%	10.2%	9.3%	9.0%	9.4%	9.8%	10.1%	10.4%	10.4%	10.1%	9.8%
Unemployment Rate	5.5%	5.2%	6.2%	5.6%	5.3%	4.9%	5.1%	5.4%	5.9%	6.2%	6.3%	6.2%

*SAAR = Seasonally Adjusted Annual Rate

Source: Dun & Bradstreet
Dataquest
September 1989

Figure 3-9

Real GNP Growth—1985 through 1990
(1982 Constant Dollars)



0004672-16

Source: Dun & Bradstreet

Trade and External Balance

Minimal improvement in the balance of trade is expected throughout the forecast period. Capacity constraints will make further export expansion difficult in the face of rising interest rates. These factors, combined with a stabilizing dollar, will dampen the 18-month export boom. Meanwhile, demand for imports will likely shrink as well in response to the projected consumer and business spending cutbacks.

Consumer Spending

Real consumer spending grew 3.8 percent in 1988 and is expected to grow in the range of 3.9 percent in 1989. Consumer spending in 1990 is projected to grow more slowly (3.4 percent) before a strong recovery in 1991. The major impact of the consumer cutback will be on consumer durable goods.

Capital Spending

Companies' capital spending plans that are in place are unlikely to be canceled in spite of recent interest rate increases. However, longer-term (from the second half of 1989 forward) plans that have not yet been finalized are likely to be affected adversely by higher interest rates, higher dollar values, and slightly reduced consumer spending. Real business fixed investment grew 9.5 percent last year; it is expected to slow to 3.6 percent growth in 1989 and to slow further to 1.6 percent growth in 1990.

Table 3-5 provides the OECD U.S. economic forecast, whereas Table 3-4 presents the D&B U.S. economic forecast. The OECD forecast is very similar to the D&B forecast; however, the OECD forecast in slightly more optimistic.

Japanese Economic Forecast—1989 and 1990

Background

The Japanese economy had a very strong 1988. Table 3-2 shows that real growth of the Japanese GNP/GDP was 5.8 percent, up from the 3.9 percent average growth from 1983 through 1986. This growth was generated by the following factors:

- Overall domestic demand grew significantly—7.3 percent (see Table 3-6).

Table 3-5

U.S. OECD Economic History and Outlook—1988 through 1990

Contributions to Change in Real GNP/GDP	1983-1986 Average	1988	1989	1990
Real GNP/GDP (Percentage of Real GNP/GDP in Previous Period)	4.1%	3.9%	3.0%	2.5%
Total Domestic Demand	5.4%	3.0%	2.8%	2.3%
Private Consumption	3.0%	1.8%	2.0%	1.5%
Private Nonresidential Investment	0.5%	1.0%	0.5%	0.5%
Change in Foreign Balance	(1.2%)	0.8%	0.3%	0
Year-to-Year Growth in Real GNP/GDP (Percentage Change SAAR* from Previous Period—1982 Dollars)	1987			
Total Domestic Demand	3.0%	3.0%	2.5%	2.3%
Private Consumption	2.7%	2.8%	3.0%	2.3%
Private Nonresidential Fixed Investment	2.8%	9.5%	4.5%	4.0%
Exported Goods/Services (Percentage Change SAAR* from Previous Period)	13.1%	19.0%	13.0%	9.8%
Imported Goods/Services (Percentage Change SAAR* from Previous Period)	7.9%	8.8%	8.8%	8.0%
Industrial Production (Percentage Change SAAR* from Previous Period)	3.8%	5.5%	4.3%	3.8%
Capacity Utilization (Percent)	80.0%	84.0%	82.0%	78.0%
Effective Exchange Rate (Index)	82.0	77.0	76.0	76.0
Real Disposable Income (RDI) (Percentage Change SAAR* from Previous Period)	6.4%	7.8%	8.0%	7.3%
Individual Savings Rate (Percent of RDI)	3.3%	4.0%	4.3%	4.3%

*SAAR = Seasonally Adjusted Annual Rate

Source: 1988 OECD Economic Outlook

- Within this domestic demand segment, consumer spending growth was a healthy 5.0 percent and capital spending growth was a sizable 16.3 percent, while government spending growth was 2.5 percent.
- A healthy export growth of 6.3 percent was balanced by consumer-driven import growth of more than 18.0 percent.

The yen remained strong against the dollar; European currencies and interest rates were low and stable. Industrial production grew so rapidly that Japan's capacity utilization rates were at an all-time high (99.0 percent) by the end of 1988. Business surveys reported in the December 1988 *OECD Economic Outlook* suggest that this triggered extensive capital spending plans for the first two quarters of 1989. Although unemployment has declined slightly to 2.5 percent from 2.6 percent (see Table 3-3), growth in wages has remained well under productivity growth, thus avoiding inflation.

Table 3-6

Japanese OECD Economic History and Outlook—1988 through 1990

Contributions to Change in Real GNP/GDP	1983-1986 Average	1988	1989	1990
Real GNP/GDP (Percentage of Real GNP/GDP in Previous Period)	3.9%	5.8%	4.5%	3.8%
Total Domestic Demand	3.3%	7.5%	5.5%	4.3%
Private Consumption	1.7%	2.8%	2.8%	2.5%
Private Nonresidential Investment	1.4%	3.3%	2.3%	1.3%
Change in Foreign Balance	0.6%	(1.8%)	(0.5%)	(0.5%)
Year-to-Year Growth in Real GNP/GDP (Percentage Change SAAR* from Previous Period—1982 Dollars)	1987			
Total Domestic Demand	5.1%	7.3%	5.0%	4.5%
Private Consumption	3.9%	5.0%	4.8%	4.5%
Private Nonresidential Fixed Investment	8.3%	16.3%	11.0%	5.3%
Exported Goods/Services (Percentage Change SAAR* from Previous Period)	3.7%	6.3%	7.0%	6.8%
Imported Goods/Services (Percentage Change SAAR* from Previous Period)	9.2%	18.3%	10.8%	9.0%
Industrial Production (Percentage Change SAAR* from Previous Period)	3.4%	8.8%	5.3%	4.5%
Capacity Utilization (Percent)	95.0%	99.0%	97.0%	95.0%
Effective Exchange Rate (Index)	170.0	187.0	193.0	193.0
Real Disposable Income (RDI) (Percentage Change SAAR* from Previous Period)	4.0%	5.5%	5.5%	5.0%
Individual Savings Rate (Percent of RDI)	16.8%	17.3%	16.8%	15.8%

*SAAR = Seasonally Adjusted Annual Rate

Source: 1988 OECD Economic Outlook

Throughout its history, Japan has worked consistently to expand foreign trade. Establishing strong trade relations with key suppliers of necessary goods and creating lucrative markets for Japan's products has been a fundamental driving force in Japan since the mid-19th century.

Since World War II, the primary component of Japan's economic redevelopment has been 20 percent annual growth of real exports. Specifically, Japan has operated with a "producer" mentality that concentrates on superior productivity and maximum competitiveness to allow successful competition in strategically defined world markets. This productivity focus ensures low labor cost, high levels of manufacturing automation, and exceptional quality. Over the past 25 years, this focus has resulted in Japan's increasing domination of many large world markets and emergence as the world's largest creditor nation.

By 1985, the G-7 ministers' concern over escalating external imbalances between countries redefined Japan's strategic objectives to some

extent. Natural external adjustment of these imbalances required that the United States compete successfully as an exporter to world markets. Thus, the value of the dollar had to decrease against that of the yen. With Japan supporting such a strong yen, its own export competitiveness would be impaired, and imports would become less expensive, thus serving to reduce Japan's large external account surplus as well.

In order to support such a move, especially in the face of increasing oil prices at that time, Japan embarked on a strategy of stimulating its economy through increased domestic demand. During 1986, the Japanese government initiated numerous government-sponsored public construction projects as well as residential housing programs to replace export growth as the main stimulus of the economy. As a result, 1987 domestic demand grew 5.1 percent, primarily driven by these programs as real export growth commenced to decline. By mid-1987, the Japanese economy began more rapid growth (4.1 percent) as the world economic picture heated up from the 1986 decline in oil prices and export growth continued to exceed expectations. Thus, 1987 provided a tax surplus, which created tax reductions in early 1988, finally igniting the significant consumer spending growth for 1988.

Outlook

As shown in Table 3-6, the Japanese 1989 and 1990 OECD forecast is based on a number of important assumptions regarding key factors, outlined as follows:

- Controlled growth of domestic demand consisting of:
  - Public spending
  - Consumer spending
  - Capital spending
- Import growth to balance exports and contain or reduce the large external surplus
- Continued avoidance of inflationary price increases in spite of tight capacity restrictions and a tight labor market

Japan's Domestic Demand Growth. Maintenance of healthy domestic demand growth is key to Japan's continued economic growth while reducing its role as the world's largest creditor. The large increases in real disposable income and employment during 1987 and 1988 have fueled a consumer buying spree that must continue. Capital spending—the further expansion of capacity and development of new technologies—is expected to continue, but at a slower pace through the forecast period. The OECD forecast in Table 3-6 shows consumer spending declining slightly by 1990 to 4.5 percent from 1989's 4.8 percent level. Furthermore, it shows a more sharp decline in private business capital spending to 11.0 percent in 1989 and 5.3 percent in 1990. Government spending is forecast to continue at a slightly higher 2.8 percent level through 1990. Thus, total domestic demand growth should decline to 5.0 percent in 1989 and 4.5 percent in 1990.

Import Growth to Reduce External Surplus. The OECD forecasts that Japan's export growth will increase slightly to 7.0 percent in 1989 before a slight decline to 6.8 percent in 1990.

Growth of imports is forecast to fall to 10.8 percent in 1989 and 9.0 percent in 1990 as total domestic demand declines throughout the period. Thus, although exports still are forecast to experience healthy growth, import growth remains high enough to create a reduction in the external account surplus from $79 billion to $72 billion by 1990.

Japan's Inflation. As measured by the real GNP/GDP price deflator growth, the OECD forecasts some increase in inflation in Japan during the next two years. Table 3-3 projects such an increase to 1.0 percent in 1989 and 1.5 percent in 1990, exceeding 1988's 0.3 percent growth level. This inflation increase is expected because of extremely tight labor markets, higher-priced imports as the yen exchange against U.S. and European currencies eases a bit, and slightly higher domestic prices due to capacity constraints. Relative to the United States, Canada, and Great Britain, this slight increase in inflation is not regarded as a significant concern as long as it remains at these forecast levels.

European Economic Forecast—1989 and 1990

Background

Starting in mid-1987 and continuing through 1988, the four major European countries (Germany, Great Britain, Italy, and France) collectively enjoyed a 3.8 percent annual average GNP/GDP growth rate. The total of 17 European OECD member countries experienced a nearly equivalent 3.5 percent growth through 1988. As Tables 3-1 and 3-2 show, this dynamic increase in economic activity across all of Europe has been the result of the following conditions:

- Increasing consumer and enterprise levels of confidence that inflation and currency exchange market instability will not reappear
- Increased business and personal disposable income through high business profits and somewhat lower interest rates and taxes resulting from the U.S. import shopping spree during the mid-1980s
- Increased domestic demand caused by expanding private business capital spending on increased productivity through modernization and expanding automation and, to a lesser extent, increasing consumer spending stimulated by credit liberalization, lower interest rates, and lower-priced imports

The growth in exports to the United States in the mid-1980s was sharply reduced across West Germany, Great Britain, France, and Italy in early 1986. As these countries worked to strengthen their currencies against the dollar, imports became cheaper and exports to the United States slowed. As oil prices fell during 1986, almost all of the European nations initiated programs to improve productivity and competitiveness in the world market. The resulting expansion of private business capital spending subsequently stimulated economic growth across all the European countries by mid-1987. The specific economic status of each of the four major European countries is outlined in the following paragraphs.

West Germany

West Germany, the previous major beneficiary of increased U.S. imports, experienced almost no real growth in exports in 1986 and 1987. Therefore, the German economy was quite weak through the first half of 1987. However, Germany repositioned its export sales efforts to focus more on the European community and has become the leader in industrial modernization and automation. The economy experienced a notable rise in private business capital spending in the second half of 1987, which continued through 1988. A dynamic increase in export growth to 5.5 percent further stimulated a significant increase in GNP/GDP growth to 3.8 percent for 1988.

Great Britain

Great Britain can boast the highest average rate of real GNP/GDP growth (3.8 percent) over the last four years among the major industrialized countries. In 1988, it experienced a strong 4.3 percent growth in real GNP/GDP. Over the past few years, this has been fueled by healthy private consumption and strong export growth. Most recently, export growth has slowed due to loss of competitiveness induced by currency exchange rates, but export growth has been replaced by stronger domestic demand growth (5.8 percent), stimulated by more liberal credit and lower interest rates. This led the United Kingdom to the position of more rapid expansion of domestic demand than potential output, resulting in associated inflationary pressures and widening external account deficits.

Italy

With 2.8 percent real GDP growth in 1987 and 3.1 percent in 1988, Italy has surpassed Britain and France to rank as the fourth largest economy behind the United States, Japan, and West Germany. Traditional inflation has been reduced from 21.0 percent growth in 1980 to a little more than 5.0 percent in 1987. Thousands of new small businesses have sprung from the fertile environment of the high savings rate—23.0 percent of disposable income—and plenty of entrepreneurial drive.

However, Italy is plagued with two of the problems of the U.S. economy: a huge federal deficit and a large external trade deficit. During 1986 and 1987, Italy's export growth was weak due to a fundamental lack of productivity and high labor costs. At the same time, import growth of manufactured goods, energy, and food shot up 6.3 percent, occupying an increasing share of the domestic market.

During 1988, a recovery of export growth and the slowing of imports decreased the deficit trade balance, and the pace of economic growth slowed slightly. But 1988 failed to provide the federal budget balancing that was envisioned. Inflation pressures and potential widening of the trade deficit are expected to continue unless the Italian government can do a better job controlling its spending.

France

Historically, France has been an aggressive and successful exporting country with export growth comparable to that of Japan in the 1970s. As the franc appreciated and oil-exporting countries grew less rapidly, the value of exports fell below that of imports in 1982. By 1986, the government had initiated a number of programs to stimulate domestic demand and reinvigorate lagging economic growth. By 1987, increased capital spending for modernization and productivity improvements started generating increased domestic demand and economic growth.

Tax reductions in 1988, along with continued capital spending, stimulated average annual growth of real GNP/GDP to the 3.3 percent level for 1988. Increased competitiveness generated a strong 7.8 percent growth in exports during 1988, which reversed the stagnant export growth trend of many years.

Assumptions for European Economic Forecast

The OECD forecast for the 17 European countries is shown in Table 3-7. This forecast is based on the following assumptions:

- Domestic demand in the larger countries will slow somewhat due to various monetary tightening and fiscal budget balancing policies. For all OECD European countries, the domestic demand growth is forecast to decrease to 3.0 percent in 1989 and 2.8 percent in 1990. Real GNP/GDP growth will decline from 1988's level of 3.5 percent to 3.0 percent in 1989 and 2.5 percent in 1990.

- Business capital investment is forecast to remain brisk, but will show a slight decline over the forecast period.

- The importance of consumer spending as the demand driver for total domestic demand will increase, but the annual growth of consumer spending will decrease somewhat.

- Inflation in the 17 OECD countries is forecast to grow at the same 4.5 percent rate experienced in 1988 and thus will not be a source of destabilization over the forecast period. Although inflation pressures are mounting in Britain and Italy, the OECD forecasts that these will be controlled by the fiscal and monetary policies during 1989, and that overall inflation across Europe will remain stable and flat.

- As business investment in productivity starts to pay off, labor costs and unemployment will remain stable during the forecast period.

Newly Industrialized Countries Economic Forecast

Background

The Asian NICs reported on by the *OECD Economic Outlook* are South Korea, Taiwan, Singapore, and Hong Kong. These countries are not member nations of the OECD, so economic data as extensive as that for its member nations is not available, nor does the OECD provide forecasts in the same level of detail as those for members. However, the OECD does track certain data, primarily trade related, in order to understand the impact of these countries on the member nations. Therefore, the data and projections contained in this section are less detailed than for other countries and are based on a combination of OECD and U.S. DOC data (see Table 3-8).

The Asian NICs have been the primary countries of choice to receive large investments in manufacturing plants and equipment, primarily from Japan and the United States during the late 1970s and most of the 1980s. As a result, these countries now are emerging as worthy competitors in the world market for manufactured goods, especially in the electronics industry. As such, over the past three years, these countries have captured a prodigious share of the world market, especially in Japan and the United States, and to a lesser extent, Europe. They have, however, accomplished this while constricting imports to their own domestic markets through a variety of trade restrictions, tariffs, and a far less competitive currency exchange position against the dollar.

Table 3-7

European OECD Economic History and Outlook—1987 through 1990

Contributions to Change in Real GNP/GDP	1983-1986 Average	1988	1989	1990
Real GNP/GDP Europe (17 Countries) (Percentage of Real GNP/GDP in Previous Period)	3.9%	5.8%	4.5%	3.8%
Total Domestic Demand	3.3%	7.5%	5.5%	4.3%
Private Consumption	1.7%	2.8%	2.8%	2.5%
Private Nonresidential Investment	1.4%	3.3%	2.3%	1.3%
Change in Foreign Balance	0.6%	(1.8%)	(0.5%)	(0.5%)
Year-to-Year Growth in Real GNP/GDP (Percentage Change SAAR* from Previous Period)	**1987**			
West Germany				
Total Domestic Demand	3.1%	4.0%	2.0%	2.8%
Private Consumption	3.5%	2.8%	2.0%	3.5%
Private Nonresidential Fixed Investment	3.3%	7.5%	6.8%	5.5%
Exported Goods/Services (Percentage Change SAAR* from Previous Period)	0.8%	5.5%	6.8%	6.5%
Imported Goods/Services (Percentage Change SAAR* from Previous Period)	4.9%	7.0%	6.0%	6.5%
Industrial Production (Percentage Change SAAR* from Previous Period)	0.3%	3.0%	2.5%	2.8%
Capacity Utilization (Percent)	95.0%	99.0%	97.0%	95.0%
Effective Exchange Rate (Index)	124.0	124.0	124.0	125.0
Real Disposable Income (RDI) (Percentage Change SAAR* from Previous Period)	4.2%	5.0%	3.8%	5.3%
Individual Savings Rate (Percent of RDI)	12.4%	13.3%	12.3%	12.5%
Great Britain				
Total Domestic Demand	4.3%	5.8%	3.8%	2.5%
Private Consumption	5.1%	5.8%	3.4%	2.8%
Private Nonresidential Fixed Investment	10.3%	13.3%	8.5%	4.5%
Exported Goods/Services (Percentage Change SAAR* from Previous Period)	5.5%	1.3%	4.5%	3.5%
Imported Goods/Services (Percentage Change SAAR* from Previous Period)	7.3%	10.8%	6.5%	5.0%

(Continued)

Table 3-7 (Continued)

European OECD Economic History and Outlook—1987 through 1990

Contributions to Change in Real GNP/GDP	1987	1988	1989	1990
Industrial Production (Percentage Change SAAR* from Previous Period)	5.8%	6.5%	3.8%	2.3%
Capacity Utilization (Percent)				
Effective Exchange Rate (Index)	82.0	87.0	88.0	88.0
Real Disposable Income (RDI) (Percentage Change SAAR* from Previous Period)	7.0%	8.8%	9.0%	7.5%
Individual Savings Rate (Percent of RDI)	5.4%	3.8%	3.5%	3.5%
Italy				
Total Domestic Demand	4.6%	4.0%	4.0%	3.0%
Private Consumption	4.3%	4.0%	3.5%	3.0%
Private Nonresidential Fixed Investment	11.5%	7.5%	6.0%	5.3%
Exported Goods/Services (Percentage Change SAAR* from Previous Period)	3.6%	6.5%	4.8%	5.0%
Imported Goods/Services (Percentage Change SAAR* from Previous Period)	10.0%	7.5%	7.0%	5.8%
Industrial Production (Percentage Change SAAR* from Previous Period)	4.0%	4.5%	4.0%	3.0%
Capacity Utilization (Percent)	78.0%	78.0%	80.0%	80.0%
Effective Exchange Rate (Index)	93.0	91.0	91.0	91.0
Real Disposable Income (RDI) (Percentage Change SAAR* from Previous Period)	7.9%	8.0%	7.3%	6.8%
Individual Savings Rate (Percent of RDI)	21.9%	21.3%	20.8%	20.3%
France				
Total Domestic Demand	3.4%	3.5%	3.3%	2.5%
Private Consumption	2.4%	2.5%	2.5%	2.0%
Private Nonresidential Fixed Investment	4.4%	9.3%	7.5%	5.3%
Exported Goods/Services (Percentage Change SAAR* from Previous Period)	1.7%	7.8%	6.8%	7.0%
Imported Goods/Services (Percentage Change SAAR* from Previous Period)	6.4%	7.8%	7.3%	6.3%

(Continued)

Table 3-7 (Continued)

European OECD Economic History and Outlook—1987 through 1990

Contributions to Change in Real GNP/GDP	1987	1988	1989	1990
Industrial Production (Percentage Change SAAR* from Previous Period)	2.0%	5.0%	4.3%	3.3%
Capacity Utilization (Percent)	95.0%			
Effective Exchange Rate (Index)	96.0	95.0	94.0	94.0
Real Disposable Income (RDI) (Percentage Change SAAR* from Previous Period)	4.2%	5.0%	3.4%	5.3%
Individual Savings Rate (Percent of RDI)	12.4%	13.3%	12.8%	12.5%

*SAAR = Seasonally Adjusted Annual Rate

Source: 1988 OECD Economic Outlook

Figure 3-10 shows the real GNP of these countries and the components of growth during 1987. South Korea and Taiwan have been the major beneficiaries of the appreciation of the yen against the U.S. dollar, the Taiwanese dollar, and the Korean won.

South Korea

South Korea has enjoyed more than 12 percent annual GDP growth for the past three years. The country has been heavily dependent on importing Japanese capital equipment for its continuing manufacturing expansion, thereby building up a sizable trade deficit with Japan while building a large export surplus with the United States. The South Korean government has initiated programs to redirect export efforts into Japan and away from the United States to balance this situation. As seen in Table 3-8, South Korea is forecast to realize slightly slower annual growth of real GDP (8 percent) through 1990.

Taiwan

Taiwan's capital spending has been one-third less than that of South Korea as a percent of GDP, so Taiwan has realized a slightly slower rate of growth in industrial production. However, the Taiwanese government is stimulating more rapid growth by sponsoring centralized industrial parks and technology research centers to attract strategic alliances with both Taiwanese and foreign companies.

From Table 3-8, Taiwan's forecast annual GDP growth for 1989 is 7.0 percent. This is down slightly from the 7.3 percent level of 1988 and the 10.1 percent level of 1987. Taiwan's current account surplus was forecast by the OECD to be halved in 1988, reflecting increased import growth following tariff reductions and currency appreciation against the dollar.

Singapore

Singapore is a recognized base for multinational manufacturing, particularly of electronic products. More than 180 foreign companies have established plants in Singapore in response to a series of lucrative government incentives.

Figure 3-10

NICs' Components of 1987 GNP

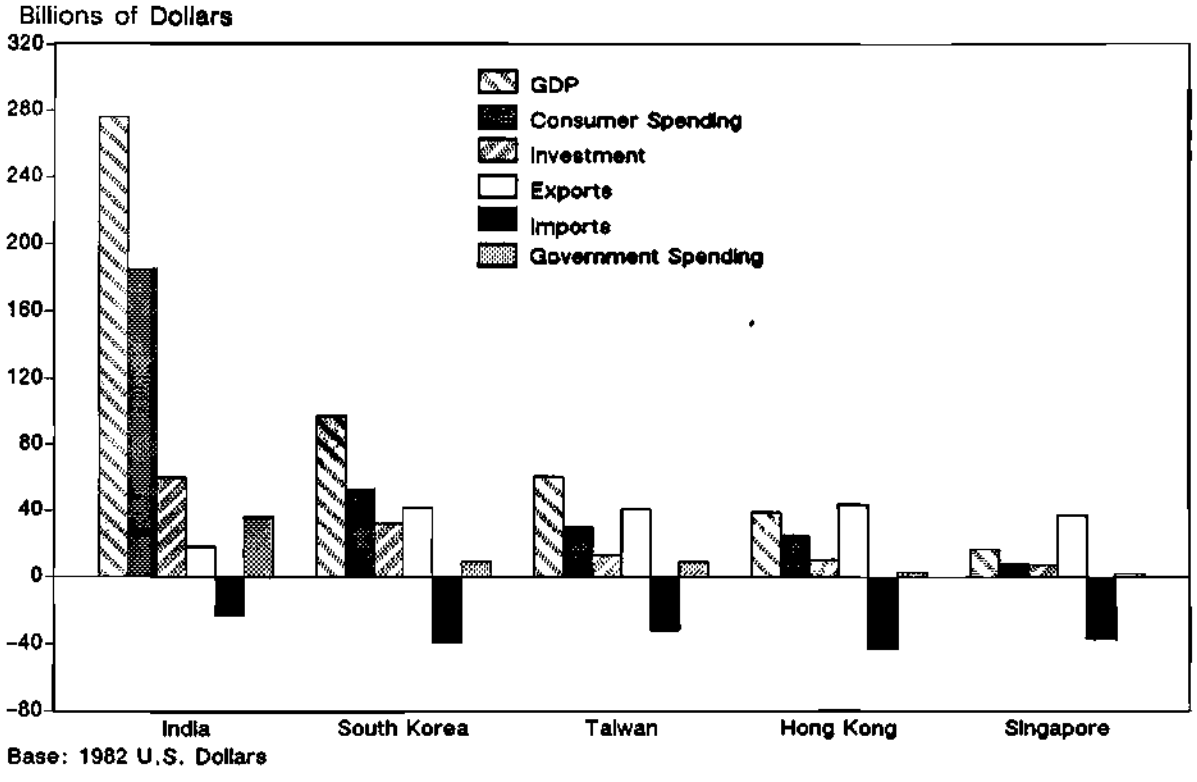


Table 3-8

Asian NIC Economic History and Outlook—1988 through 1990

Contributions to Change in Real GNP/GDP	1988	1989	1990
Real GNP/GDP Europe (Four Countries) (Percentage of Real GNP/GDP in Previous Period)	9.5%	7.5%	6.9%
Total Domestic Demand	9.3%	7.1%	6.9%
Private Consumption	4.8%	3.8%	3.7%
Private Nonresidential Investment	2.9%	2.3%	2.3%
Change in Foreign Balance	(3.9%)	(2.2%)	(1.2%)

(Continued)

Table 3-8 (Continued)

Asian NIC Economic History and Outlook—1988 through 1990

Contributions to Change in Real GNP/GDP	1988	1989	1990
Year-to-Year Growth in Real GNP/GDP (Percentage Change SAAR* from Previous Period—1982 Dollars)			
Total Domestic Demand			
Private Consumption	9.8%	7.6%	7.5%
Private Nonresidential Fixed Investment	9.6%	7.6%	7.5%
Exported Goods/Services	15.0%	13.0%	11.0%
Imported Goods/Services	24.0%	17.0%	13.0%
Effective Exchange Rate (Index)	187.0	193.0	193.0
	1988	**1989**	**1990**
South Korea			
Real GNP/GDP	12.1%	8.0%	8.0%
Private Consumption	12.0%	8.0%	8.0%
Private Nonresidential Fixed Investment	12.0%	8.0%	8.0%
Imported Goods/Services	23.0%	17.0%	12.0%
Exported Goods/Services	16.0%	14.0%	12.0%
Taiwan			
Real GNP/GDP	7.3%	7.0%	7.0%
Private Consumption	7.3%	7.0%	7.0%
Private Nonresidential Fixed Investment	7.3%	7.0%	7.0%
Imported Goods/Services	32.0%	19.0%	12.0%
Exported Goods/Services (Percent of RDI**)	8.0%	10.0%	10.0%
Singapore			
Real GNP/GDP	10.5%	9.8%	9.0%
Private Consumption	10.5%	9.8%	9.0%
Private Nonresidential Fixed Investment	10.5%	9.8%	9.0%
Imported Goods/Services	16.0%	15.0%	15.0%
Exported Goods/Services	11.0%	12.0%	10.0%

(Continued)

Table 3-8 (Continued)

Asian NIC Economic History and Outlook—1988 through 1990

Contributions to Change in Real GNP/GDP	1988	1989	1990
Hong Kong			
Real GNP/GDP	8.9%	5.7%	5.7%
Private Consumption	8.9%	5.7%	5.7%
Private Nonresidential Fixed Investment	8.9%	5.7%	5.7%
Imported Goods/Services	23.0%	18.0%	16.0%
Exported Goods/Services	24.0%	16.0%	14.0%

*SAAR = Seasonally Adjusted Annual Rate
**RDI = Real Disposable Income

Source: 1988 OECD Economic Outlook

Hong Kong

Hong Kong is becoming a major reexporting country with more than 40.0 percent of its exports to the United States, primarily in soft goods and apparel. This strong trade with the United States contributed strongly to a real GDP annual growth rate in 1987 of 12.6 percent. The strong U.S. trade is primarily because, unlike the Taiwanese dollar or the Korean won, the Hong Kong dollar has not appreciated against the U.S. dollar since 1985.

Real GDP growth is forecast to be 5.7 percent in 1989, down from 8.9 percent in 1988. Although growth is expected be down in 1989, it still is strong in actual revenue. Growth is primarily driven by strong domestic demand and increased trade with the People's Republic of China (PRC). Increased trade with the PRC has a significant impact on Hong Kong because the Chinese renminbi has dropped more than 20.0 percent against the Hong Kong dollar, and more than 45.0 percent of Hong Kong's food and consumer goods comes from the PRC.

CHAPTER 4

Electronic Equipment Segment of the Economy

Introduction

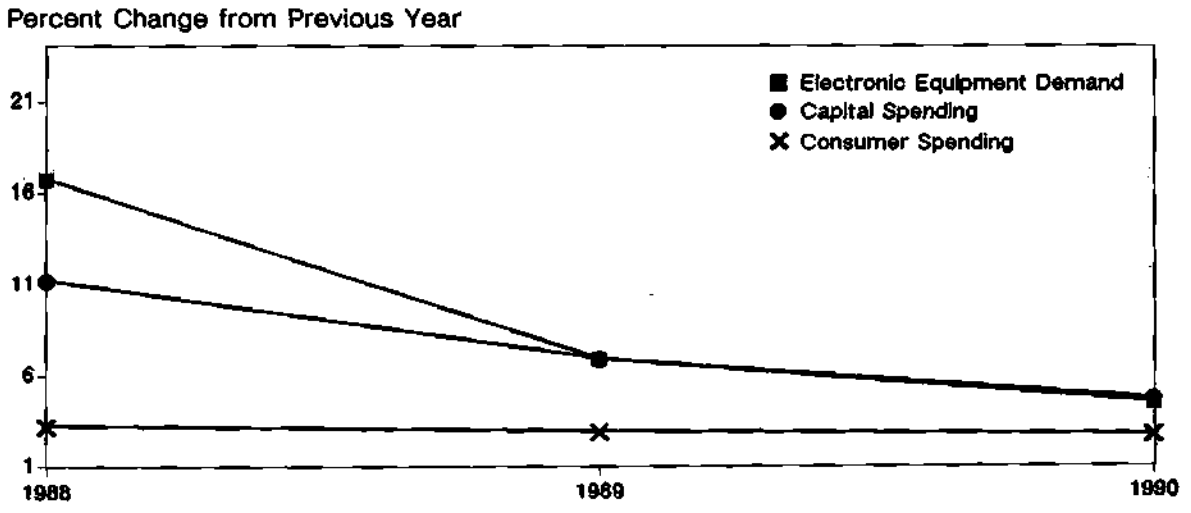
The steadily growing electronic equipment segment of the global economy is a major contributor to worldwide economic growth. Dataquest estimates that 1988 worldwide electronic equipment sales accounted for nearly 8 percent of OECD members' output of goods and services. In 1988, that amounted to $760 billion out of $10 trillion, measured in current U.S. dollars. Illustrative of this growth and contribution is the fact that electronic equipment progressed from less than 3 percent of the OECD output in the mid-1970s to just shy of 5 percent in 1984 to nearly 8 percent in 1988.

Chapter 3 developed the headwaters of the waterfall of demand and established that the global economy has been expanding vigorously since 1987. The major force behind this recent worldwide economic expansion has been spending related to private, fixed, nonresidential investments (capital spending by businesses), as shown in Figure 4-1.

As mentioned in Chapter 3, although worldwide consumer spending has declined considerably as an economic driving force from its 1985 historic levels of more than 5 percent annual growth, it has been on the rise in some regions during the past two years. This increase has occurred in countries that have enjoyed recent buoyant economic growth—Japan, Asian NICs, the United Kingdom, and Germany. Although Japanese and Asian Rest of World (ROW) consumer spending has been less than that of the United Kingdom or Germany, it has not been an insignificant contributor to worldwide electronic equipment growth, as shown in Figure 4-1.

Figure 4-1

Worldwide Electronic Equipment Demand versus Capital and Consumer Spending 1988-1990 Annual Growth



Source: Dataquest September 1989

Because the electronic equipment industry sells products in all three economic sectors—private business, consumer, and government—the industry has been able to take advantage of the growth in consumer and capital spending. It therefore has enjoyed significant growth worldwide over the last two years. Dataquest estimates that annual growth for electronic equipment exceeded 23 percent in 1987, whereas 1988 growth was substantial but slower—approximately 17 percent (see Figure 4-1).

This chapter takes the first step down the waterfall of demand. In the process, it develops the following three important topics:

- Demand for electronic equipment—This includes a discussion of worldwide and regional economic demand drivers.
- Production of electronic equipment—Key regional economic and competitive issues discussed in Chapter 3 are used to relate worldwide demand to worldwide and regional forecasts of electronic equipment production.
- Procurement of semiconductor devices—Regional electronic equipment production forecasts are used to generate regional forecasts of semiconductor expenditures for 1989 and 1990. This is addressed as a strategic issue within the section entitled "Electronic Equipment Production."

Electronic Equipment Demand

This section on electronic equipment demand provides the following information:

- Background for electronic equipment demand
- Electronic equipment demand forecast for 1989 and 1990
- Strategic issues regarding the electronic equipment demand forecast

Background

The background information for electronic equipment demand explores the following areas:

- Equipment market segments—What is included in the electronic equipment market?
- Market segment growth—What is driving equipment market growth?
- Sources of demand—Who buys electronic equipment?
- Regional equipment demand—Where is electronic equipment purchased?

Equipment Market Segments

Dataquest segments the electronics industry into six major application markets, defined as follows:

- Data processing
- Consumer
- Industrial
- Communications
- Military
- Transportation

Data Processing

Data processing comprises all equipment that functions as information processors, including all personal computers, regardless of price or the environment in which they are used. About 10 percent of this segment's equipment is assumed to be purchased by the consumer sector of the economy. The balance (90 percent) is purchased by the private business and government sectors.

Consumer

The consumer segment comprises equipment that is used primarily in the home for personal use, such as audio and video equipment and household appliances. All equipment in this segment is purchased by the consumer sector of the economy.

Industrial

The industrial segment consists of all manufacturing-related equipment, including scientific, medical, and dedicated systems. It is assumed that all equipment in this segment is purchased by the capital spending sector of the economy.

Communications

Most of the communications segment is made up of telecommunications equipment, which Dataquest classifies as customer-premises and public telecommunications equipment, and all other com-

munications equipment, such as radio transmission, studio, and broadcast equipment. All of the equipment in this sector is assumed to be purchased by either the capital spending or government purchasing sectors of the economy.

Military

Military equipment is primarily defense-oriented electronic equipment and thus does not include all electronic equipment procured by the government. In order to avoid double-counting, equipment that belongs in an already defined application market segment is not included here. All equipment in this segment is purchased by the government (defense) spending sector of the economy.

Transportation

Transportation consists mainly of automotive and light-truck electronics. All equipment in this segment is assumed to be purchased by the consumer sector of the economy.

Market Segment Growth

The worldwide electronics industry demand growth by application market is illustrated in Figure 4-2. Growth was driven primarily by the data processing and consumer markets. Figure 4-3 shows that the share of these two segments has increased from 55 percent in 1986 to 59 percent in 1988, at the expense of the military and industrial segments, which fell from 29 percent in 1986 to 24 percent in 1988.

Major growth products within the data processing and consumer markets have been personal computers, workstations, storage peripherals, terminals, personal printers, VCRs, and compact disc players. These growth products have the following common attributes:

- High semiconductor content
- High unit volume
- Large market (All of these products are used by individuals and thus are assured of a large total available market.)

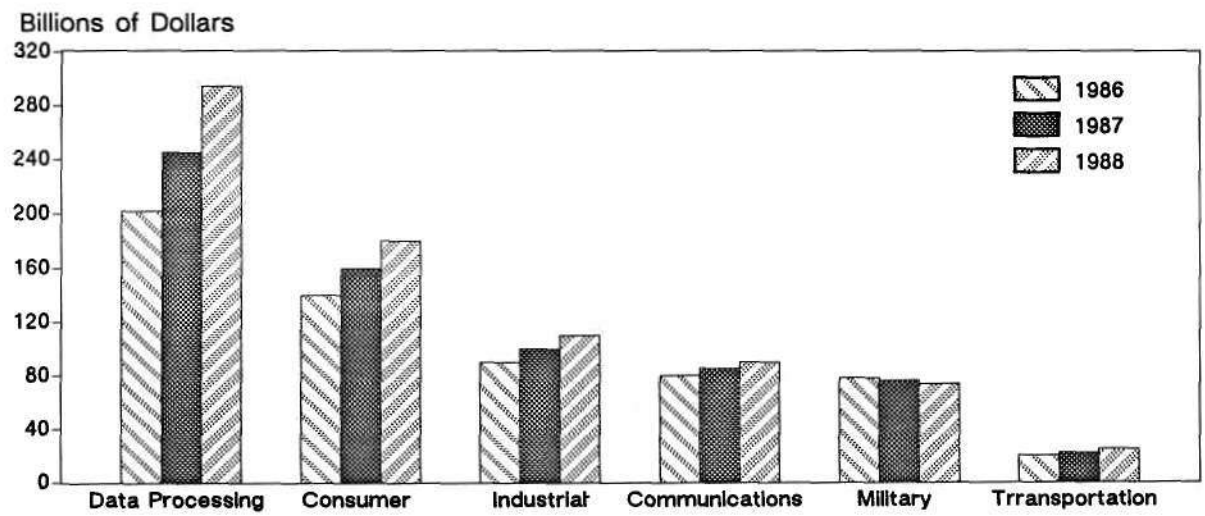
Demand Sources

The growth in worldwide demand for electronic equipment is determined by the growth in worldwide spending from the following three major economic sectors:

- Private, fixed, nonresidential investments (otherwise known as capital spending)
- Consumer spending
- Government spending

Figure 4-2

Worldwide Electronic Equipment Market Growth
by Application Market Segment—1986-1988



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Source: Dataquest
September 1989

Figure 4-3

Worldwide Electronic Equipment Demand by Application Market Segment—1986 and 1988

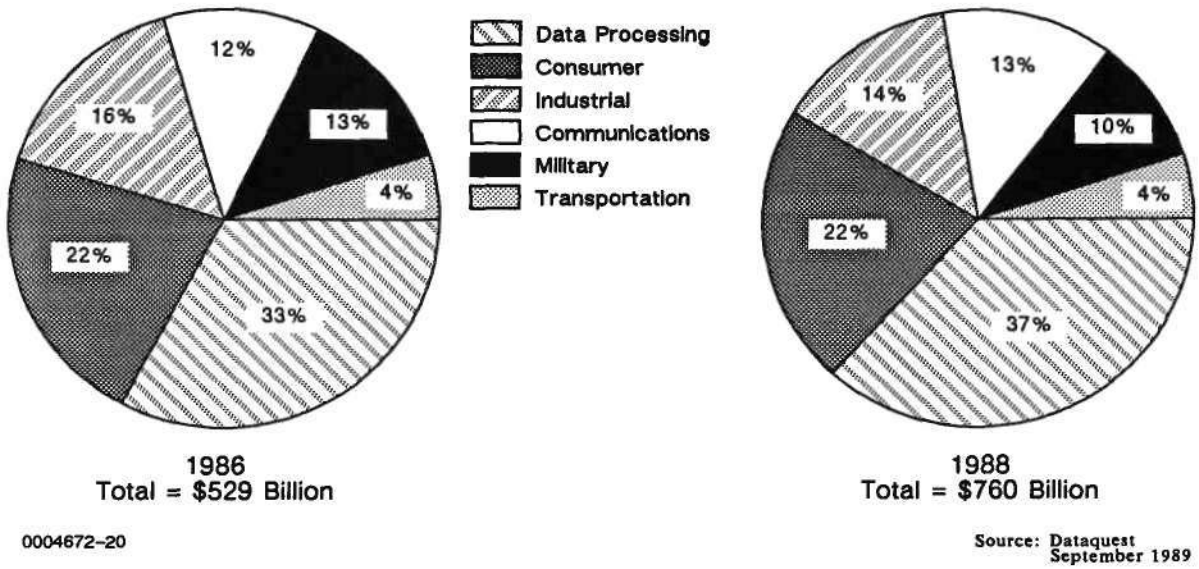


Table 4-1 presents the percent share of worldwide equipment demand that is purchased by each economic sector. It is important to note that individual market segment growth is a function of the growth of the economic sectors in which the major purchases occur. For example, the data processing, industrial, and communications segments are purchased mostly by the capital spending sector and represent nearly 60 percent of total equipment demand, as shown in Figure 4-4. The consumer and transportation segments are purchased mostly by the consumer sector and represent 30 percent of total demand. All of the military segment is purchased by government spending and represents 10 percent of the total equipment demand. The growth of the equipment demand as a whole therefore is determined by the growth rates of the individual economic sectors weighted by the relative size of each sector.

Additionally, it is important to note that small changes in sector spending can have a big impact on equipment demand. As an example, Figure 4-5 compares constant 1982 dollar values of OECD worldwide consumer and capital spending with current dollar values of worldwide demand for electronic equipment. The following two observations can be made from this comparison:

- Approximately 40 percent of worldwide capital spending accounts for 60 percent of electronic equipment demand.
- Only 3 percent of worldwide consumer spending and some government spending account for the remainder (40 percent) of electronic equipment demand.

Therefore, it can be seen that any change in capital spending has a direct and significant impact on equipment demand, particularly in the data processing, communications, or industrial segments (see Figure 4-6). Furthermore, as Figure 4-7 shows, consumer and transportation segments are tied to the consumer spending sector. The consumer spending sector has been flat and is forecast to continued the same pattern, but the consumer equipment and transportation segments have experienced dynamic growth swings resulting from relatively small changes in consumer spending.

Table 4-1

Electronic Equipment Industry Worldwide Demand
by Purchasing Sector--1986-1988

Application Market	Total Demand Market ($B)	Share	1986 Capital Spending Percent	($B)	Consumer Spending Percent	($B)	Government Spending Percent	($B)
Data Processing	$175	33.1%	90.0%	$157.7	10.0%	$ 17.5	0	0
Communications	65	12.2	100.0%	64.5	0	0	0	0
Industrial	84	15.9	100.0%	84.0	0	0	0	0
Consumer	115	21.7	0	0	100.0%	114.6	0	0
Military	69	13.0	0	0	0	0	100.0%	$68.6
Transportation	22	4.1	10.0%	2.2	90.0%	19.6	0	0
Total	$530	100.0%	58.3%	$308.4	28.7%	$151.7	13.0%	$68.6

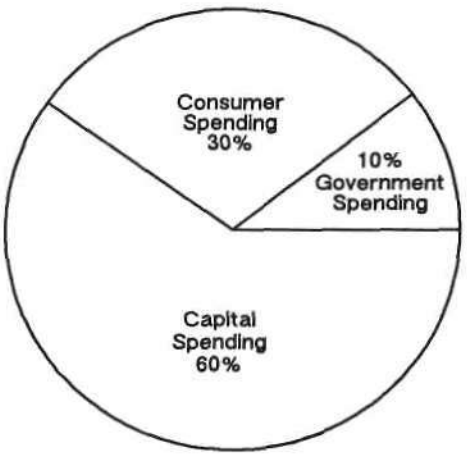
Application Market	Total Demand Market ($B)	Share	1987 Capital Spending Percent	($B)	Consumer Spending Percent	($B)	Government Spending Percent	($B)
Data Processing	$227.0	34.9%	90.0%	$204.3	10.0%	$ 22.7	0	0
Communications	84.8	13.0	100.0%	84.8	0	0	0	0
Industrial	93.9	14.4	100.0%	93.9	0	0	0	0
Consumer	141.6	21.8	0	0	100.0%	141.6	0	0
Military	73.2	11.2	0	0	0	0	100.0%	$73.2
Transportation	30.2	4.6	10.0%	3.0	90.0%	27.2	0	0
Total	$651.0	100.0%	59.3%	$386.0	29.4%	$191.5	11.2%	$73.2

Application Market	Total Demand Market ($B)	Share	1988 Capital Spending Percent	($B)	Consumer Spending Percent	($B)	Government Spending Percent	($B)
Data Processing	$275.5	36.2%	90.0%	$248.0	10.0%	$ 27.6	0	0
Communications	99.0	13.0	100.0%	99.0	0	0	0	0
Industrial	107.0	14.1	100.0%	107.0	0	0	0	0
Consumer	168.9	22.2	0	0	100.0%	168.9	0	0
Military	75.7	10.0	0	0	0	0	100.0%	$75.7
Transportation	34.2	4.5	10.0%	3.4	90.0%	30.8	0	0
Total	$760.0	100.0%	60.2%	$457.4	29.9%	$227.2	10.0%	$75.7

Source: Dataquest
September 1989

Figure 4-4

1988 Sources of Electronic Equipment Demand by Sector



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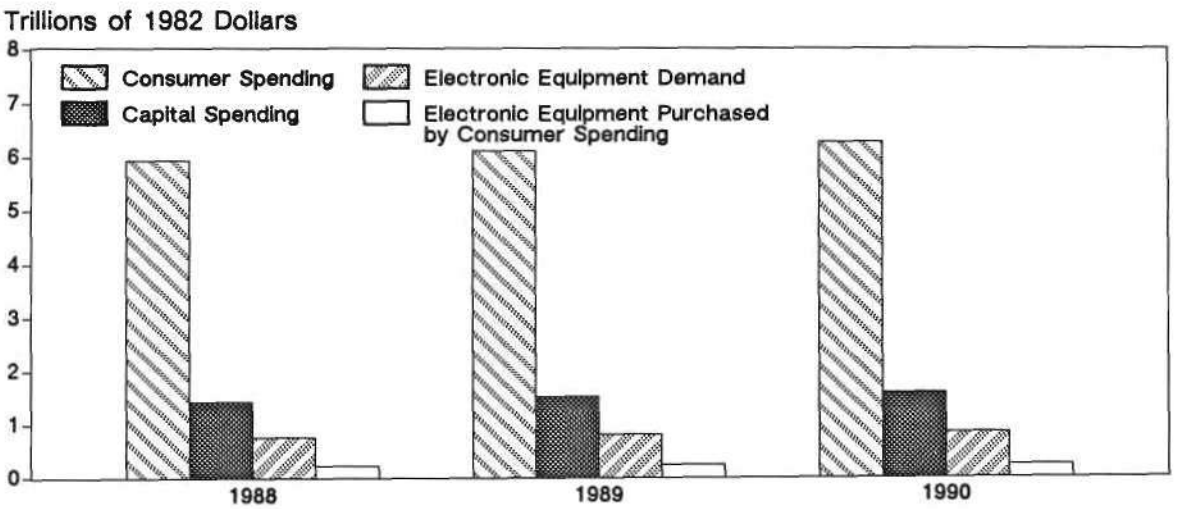
Source: Dataquest September 1989

Figure 4-5

Consumer and Capital Spending versus Electronic Equipment Demand by Sector—1988-1990



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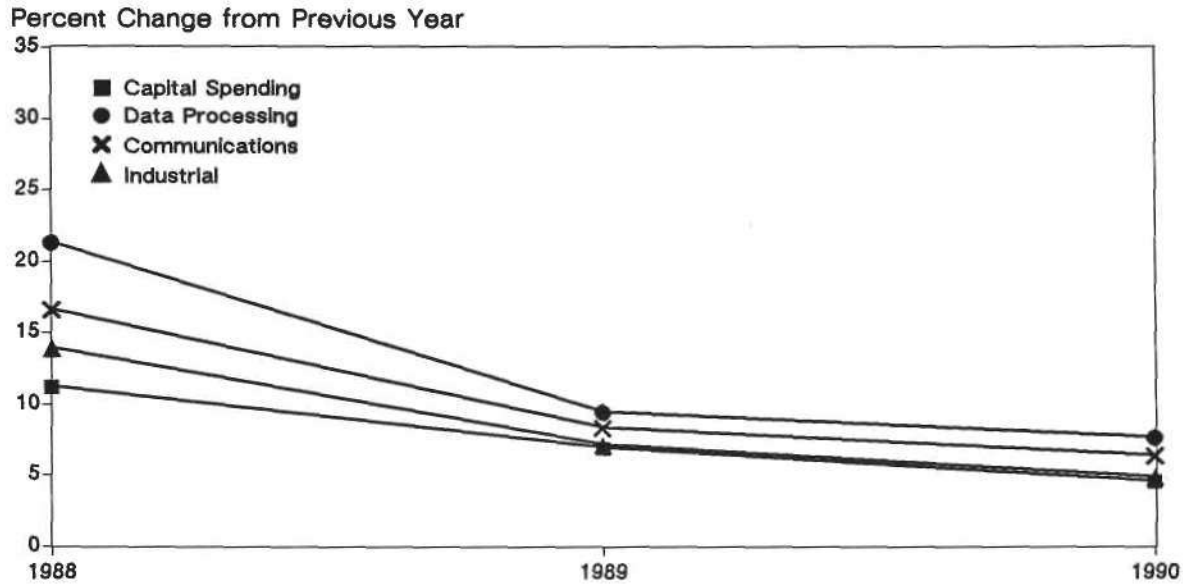
Source: Dataquest September 1989

Figure 4-6

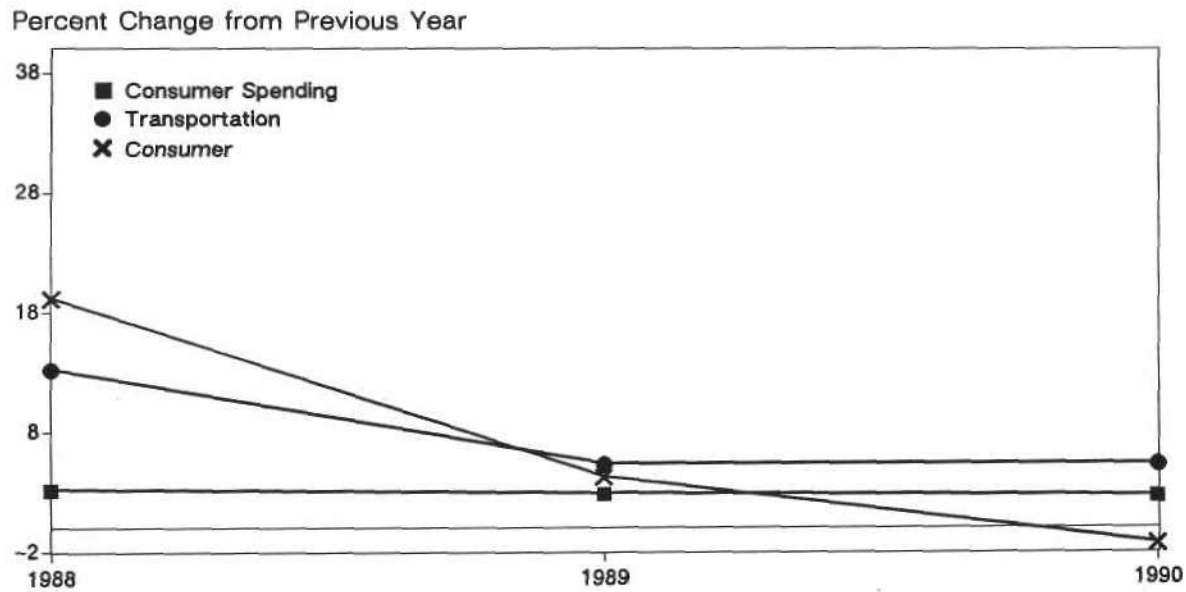
Worldwide Electronic Equipment Demand and Capital Spending by Application Market—1988-1990



Source: Dataquest September 1989

Figure 4-7

Worldwide Electronic Equipment Demand by Application Market—1988-1990



Source: Dataquest September 1989

As an historical example of how economic sector spending influences electronic equipment demand, consider the 1985 and 1986 near recession in the United States. Through 1983 and 1984, the U.S. economy was enjoying a consumer-driven shopping spree (see Chapter 3). This stimulated North American capital spending, as companies in all segments of the economy scrambled to increase capacity and productivity to participate in the boom. Figure 4-8 illustrates the high annual growth of North American consumer spending through the period—nearly 5 percent in both 1983 and 1984. The high value of the dollar drove import prices well below those of domestic products, and Japan, the Asian ROW countries, and West Germany were the major benefactors from all this spending.

By 1985, the strength of the dollar had all but choked U.S. exports. Rapidly rising interest rates, due to the high demand for funds to finance all the deficit spending, stalled capital spending growth as well. As can be seen in Figure 4-9, North American capital spending growth fell to a 7.7 percent annual growth rate in 1985 and a negative 4.5 percent in 1986.

However, from 1986 through mid-1989, North American equipment demand has been buoyant, aided by the high growth rate of North American capital spending (see Figure 4-9).

Regional Equipment Demand

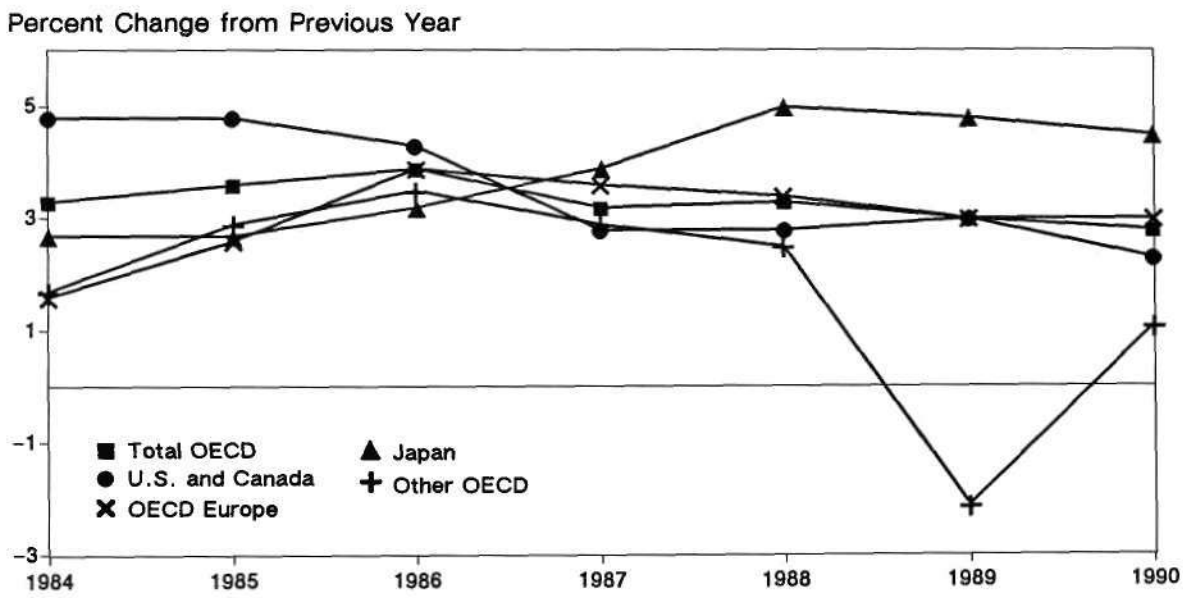
The regional equipment demand forecasts provided are based on the following assumptions:

- Individual market segment growth is a function of the economic sector in which the major purchases occur.
- Small changes in sector spending can have a large impact on equipment demand.
- Regional annual growth rates of electronic equipment demand are determined by the weighted average of the annual growth rates of consumer and capital spending within each region.
- Each region's share of electronic equipment demand is approximately equal to its share of worldwide capital spending.

Based on these assumptions and the regional growth rates shown in Figures 4-8 and 4-9, the electronic equipment demand by region for 1984 and 1988 is shown in Figure 4-10.

Figure 4-8

Worldwide and Regional Consumer Spending—1984-1990



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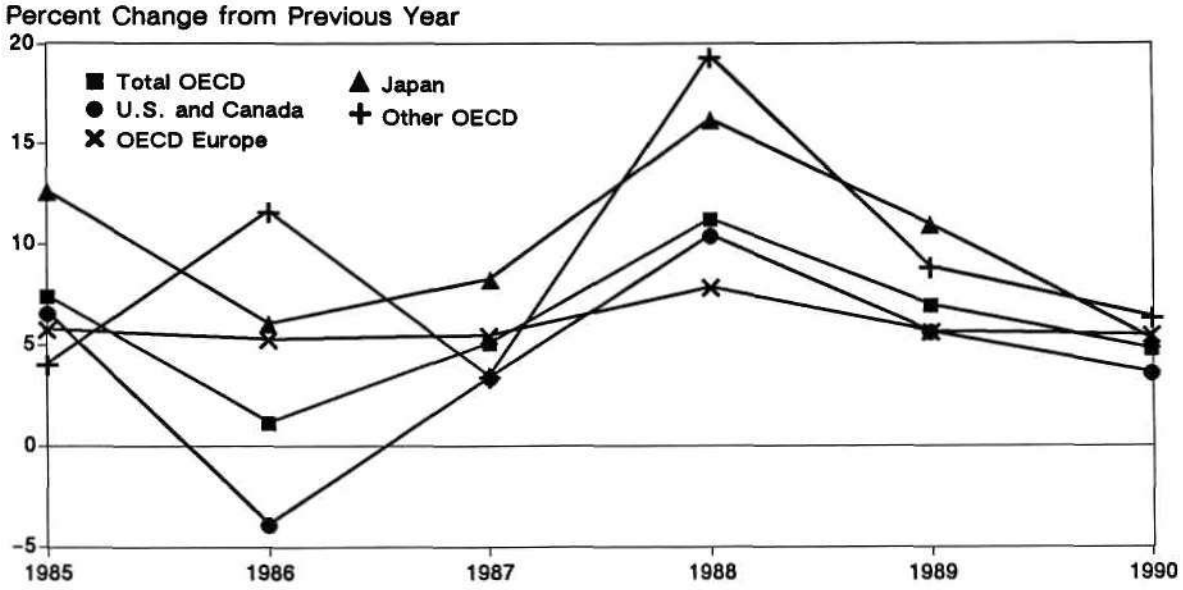
Source: Dataquest September 1989

Figure 4-9

Worldwide and Regional Capital Spending—1985-1990



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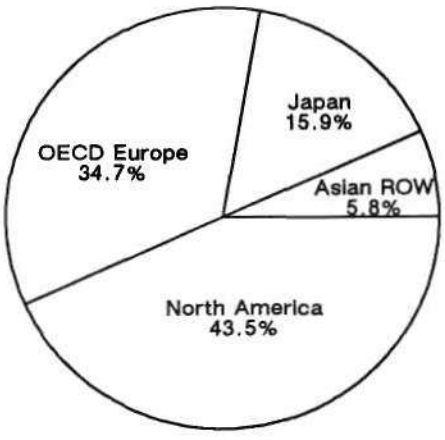
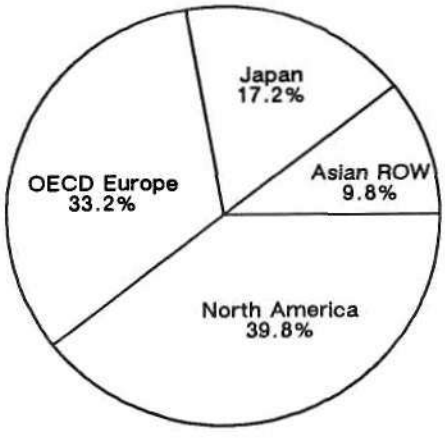
Source: Dataquest
September 1989

Figure 4-10

Worldwide Electronic Equipment Demand Share by Region—1984 and 1988



1984
Total = $420 Billion



1988
Total = $760 Billion

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Source: Dataquest
September 1989

One thing noticeable about the data in Figure 4-10 is the significant increase in the share of electronic equipment consumption by Japan and the Asian NICs. Their combined share jumped from 21.7 percent in 1984 to 27.0 percent by 1988. The fundamental reasons for these increases (as originally stated in Chapter 3) are as follows:

- Japan and the Asian NICs were the major suppliers to the U.S. import shopping spree from 1983 through 1985 period. As a result, at different times throughout the period, they have all experienced heavy capital spending growth to expand production capacity, productivity, and competitiveness. This resulted in increased demand for electronic equipment (data processing, industrial automation, and communications). Note from Figure 4-8 that Japanese capital spending remained strong through the 1985 downturn in the United States, as did that of the Asian ROW region.
- Since 1987, as the benefits of this Japanese and Asian expansion have been realized in terms of increased disposable incomes, consumer spending in these countries has surged (see Figure 4-9).

Figure 4-10 shows that the Japanese and Asian ROW regions are a growing electronic equipment market, approaching the size of the European market in 1988.

Electronic Equipment Demand Forecast—1989 and 1990

The OECD and D&B economic forecasts summarized in Chapter 3 suggest a considerable slowing of worldwide capital spending through 1990. As shown in Figure 4-11, capital spending is forecast to slow from more than 11 percent in 1988 to less than 5 percent in 1990.

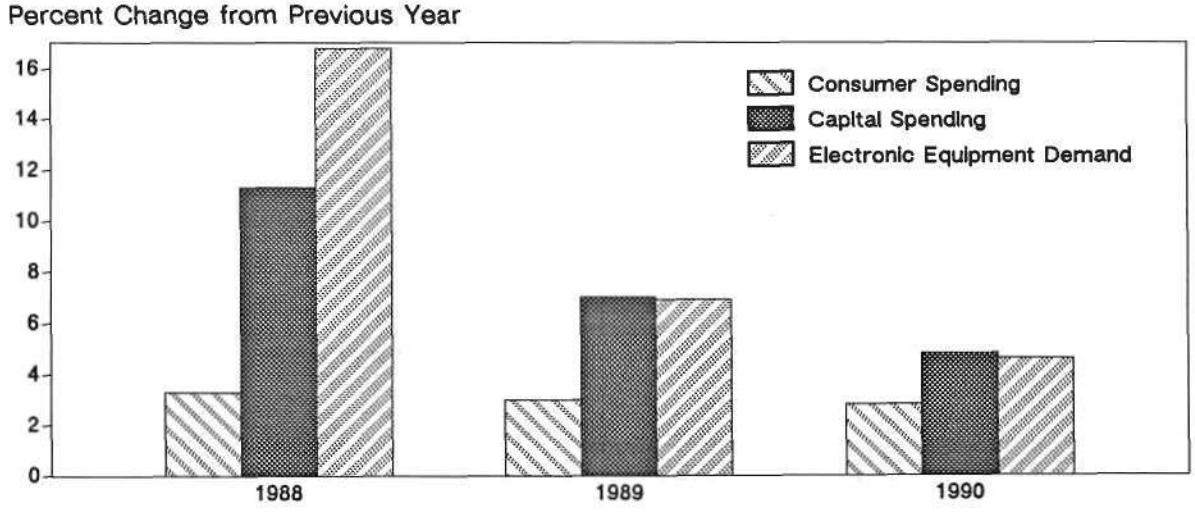
The impact that this slowdown is expected to have is that growth in demand for electronic equipment will also drop from the 17 percent level in 1988 to less than 5 percent by 1990.

The 1988 estimated demand and 1990 forecast demand by region shown in Figure 4-12 is based on the OECD forecast for capital and consumer spending by region, as summarized in Figures 4-8 and 4-9.

The 1988 through 1990 worldwide demand forecast by application market is given by Figure 4-13. This is based on Dataquest's forecast, which is shown in comparison to the OECD worldwide capital and consumer spending forecast in Figures 4-6 and 4-7.

Figure 4-11

Electronic Equipment Demand and Consumer and Capital Spending Annual Growth—1988-1990



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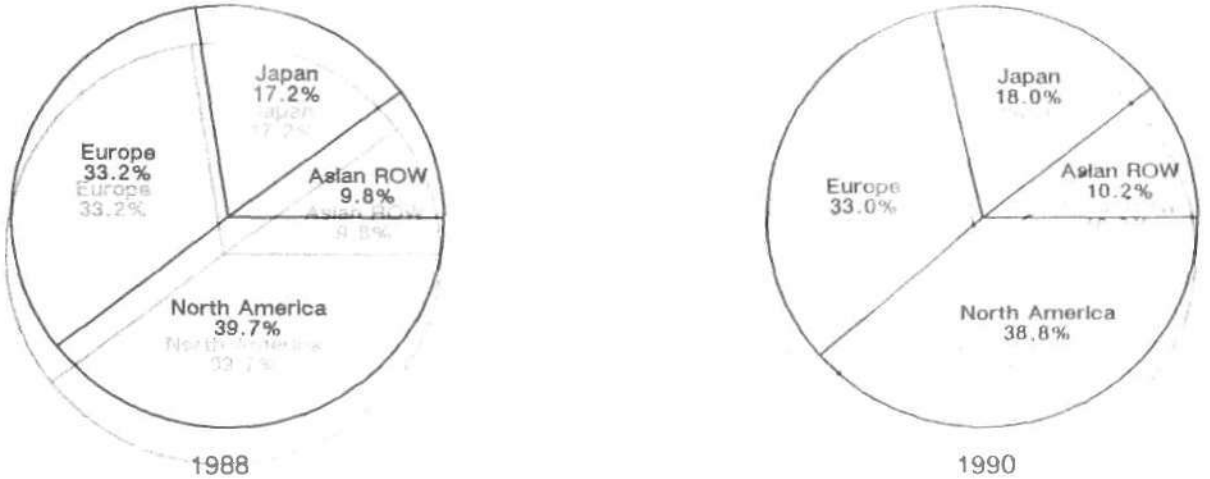
Source: Dataquest September 1989

Figure 4-12

Worldwide Electronic Equipment Demand Forecast by Region—1988 and 1990



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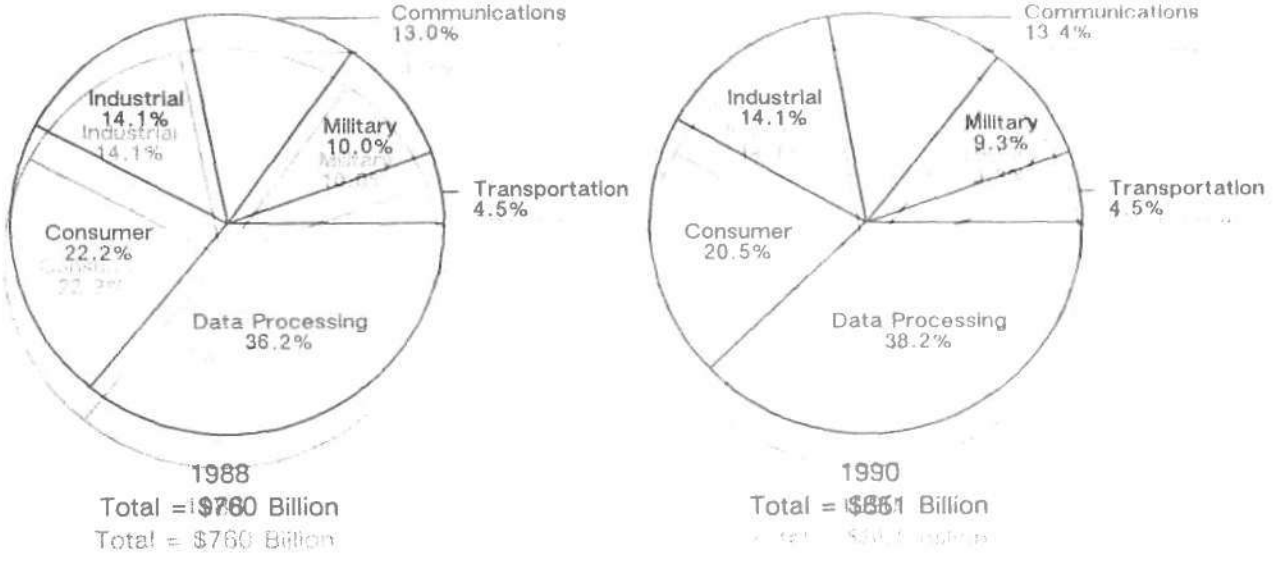
Source: Dataquest
September 1989

Figure 4-13

Worldwide Electronic Equipment Demand Share Estimate and Forecast by Application Market Share—1988 and 1990



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Source: Dataquest
September 1989

Two Strategic Issues Regarding the Demand Forecast

What Is the Regional Economic Impact on Electronic Equipment?

North America. The annual growth of the real U.S. GNP is forecast in Chapter 3 to remain relatively strong in the first half of 1989. It is expected to decline sharply from its 1988 level of 4.0 percent to an annualized rate of 1.2 percent by the third quarter and to 0.6 percent by the fourth quarter of 1989 for an average 1989 annual growth of 3.0 percent. The first quarter of 1990 is forecast to decline further to an annualized growth of negative 0.6 percent before a strong recovery in the balance of 1990. This relatively mild economic slowdown is expected to have a more dramatic effect on capital spending. Capital spending through the period is expected to average about 4.0 percent real growth as opposed to the 9.5 percent growth of 1988. As a result, the growth of North American demand for electronic equipment is expected to decline from the 16.2 percent level of 1988 to 5.8 percent in 1989 and only 2.7 percent in 1990.

On the brighter side, D&B surveys show that although overall demand for electronic products may be off, spending for computer systems, office automation, and manufacturing automation systems will remain high as companies seek to increase productivity and competitiveness.

Europe. The European electronic equipment demand is forecast to grow at an annual rate of 5.9 percent in 1989 and 5.1 percent in 1990, down from the 1988 level of 14.5 percent. Again, this is a result of the forecast slowing of real GNP/GDP growth and its amplified impact on capital spending throughout Europe. The European countries will avoid feeling the full slowdown affecting the United States, largely because of the widespread capital spending by both European and Pacific Rim countries in preparation for the European Economic Community (EEC) market consolidation in 1992.

Japan and the Asian ROW. Because the capital and consumer spending growth of Japan and the Asian NICs is not expected to fall as sharply as that of the North American and European regions, the electronic equipment demand compound annual growth rate (CAGR) in these regions remains higher than in that of the other regions. The continued investment by Japanese electronics companies in offshore production will continue to stimulate demand growth in the Asian NICs.

The demand share for electronic equipment therefore will continue to shift toward Asia and Japan (see Figure 4-12). From 1988 to 1990, the combined share of Japanese and the Asian NIC demand is forecast to grow from 27 percent to 28 percent.

What Are the Major Demand Drivers?

The application market forecast to show the highest growth still is data processing, followed by the communications and industrial segments. This is a result of the continued expansion and modernization in the Asian NICs and Japan. Modernization and productivity improvement in process in Europe also will contribute to the growth of these segments.

The slower growth of the consumer and transportation segments reflects the forecast decline in consumer spending within the regions with the largest populations—North America and Europe.

The U.S. fiscal restraint evident in the 1989 and 1990 federal defense spending budget has caused the slower growth forecast in the military segment.

Electronic Products—Largest Demand Drivers. Within those market segments showing the most demand growth, the specific products that are driving this growth are shown in Table 4-2. Table 4-3 shows those end products forecast to show the steepest decline.

Electronic Equipment Production

Electronic equipment production directly determines the demand for semiconductors. The success and growth of electronic equipment producers within a given region determines the size and growth of the total available market for semiconductors within that region.

Table 4-2

Growing Application Markets—1988-1992

	1988	1989	1992	CAGR 1988-1992
Processing Terminals	$ 0.1	$ 0.2	$ 1.0	86.5%
Optical Disk Drives	0.3	0.8	2.7	71.7%
3- to 4-Inch Rigid Disk Drives	3.1	5.3	12.7	41.8%
Workstations	2.2	2.9	6.8	33.4%
Local Area Networks (LANs)	2.6	3.6	5.8	22.2%
3.5-Inch Flexible Disk Drives	1.1	2.2	17.5	99.7%
Voice Messaging Systems	0.5	0.9	15.8	137.2%
Facsimile Machines	1.0	1.3	1.8	14.0%
Total	$10.9	$17.2	$64.1	55.7%

Source: Dataquest
September 1989

Table 4-3

Declining Application Markets—1988-1992
(Billions of Dollars)

	1988	1989	1992	CAGR 1988-1992
5.25-Inch Flexible Disk Drives	$ 1.3	$ 1.1	$0.5	(22.6%)
Alphanumeric Display Terminals	2.8	2.7	2.7	(0.8%)
Modems	1.3	1.2	0.9	(8.8%)
Line Printers	1.3	1.2	1.1	(3.2%)
Electronic Typewriters	2.4	2.4	2.0	(4.1%)
1/2-Inch Tape Drive	2.2	2.3	1.9	(4.6%)
Total	$11.3	$10.9	$9.1	(5.3%)

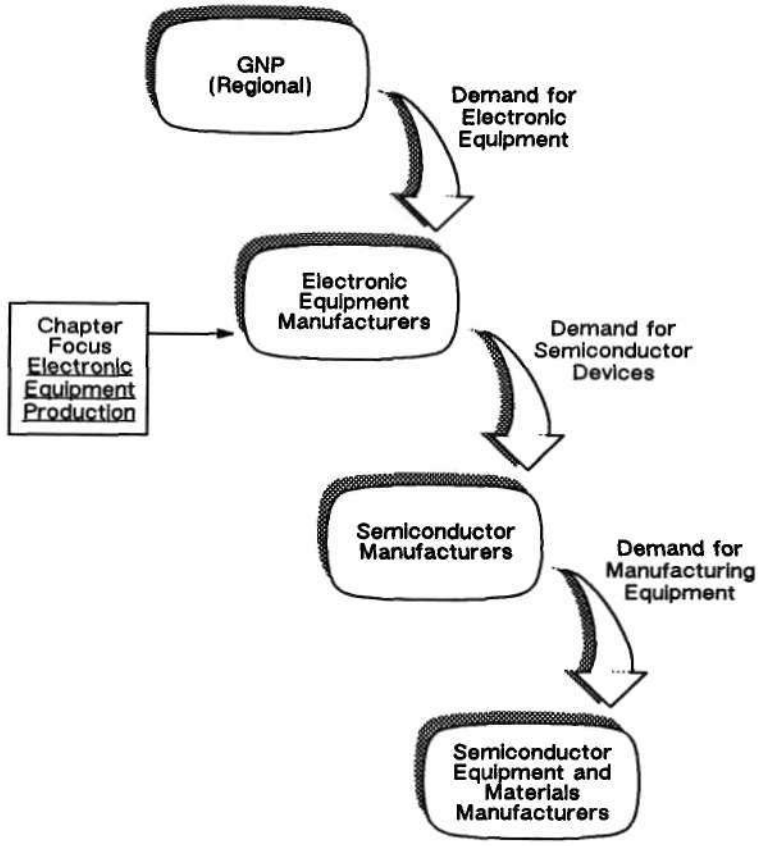
Source: Dataquest
September 1989

The success and growth of electronic equipment producers depends to a large degree on their products. However, the economic conditions of the region—labor costs, interest and currency exchange rates, and the availability of patient investment capital—play a large role as well. These factors determine productivity and hence competitiveness, thus influencing a company's ability to compete for worldwide demand for its products.

This chapter takes the next step down the demand waterfall shown in Figure 4-14 and relates the worldwide and regional demand for electronic equipment discussed above to the production of electronic equipment and hence to the demand for semiconductors.

Figure 4-14

Waterfall of Demand



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Source: B. Hesley & M. Ford

Background

Electronic equipment producers build end products by assembling printed circuit boards containing semiconductors, other electromechanical or mechanical devices, and a power supply into a package or container. The manufacturing steps are as follows:

- Fabrication of the individual subassemblies, PC boards, and packaging
- Assembly of all these pieces
- Test and verification that the product works and meets specifications

These manufacturing steps frequently involve the need for labor with good manual skills. Low-cost production translates to low-cost but highly skilled labor and considerable automation of much of the fabrication and testing portions of the process.

During the 1970s, emerging semiconductor technology enabled more and more functionality in smaller and smaller physical packages, and electronic products generally became more of a commodity. Successful producers required very large production volumes to be truly competitive.

Meanwhile, early in the 1970s, Japan began to execute a multiphased strategy to accomplish a national objective: to become a world-class producer of consumer, communications, and data processing equipment. The execution of this was truly national in scope and involved teamwork between the government, sources of patient capital, and many individual business entities.

The strategy itself embodied the following four steps:

- License the technology or manufacturing rights to a key product
- Leverage Japan's manufacturing and quality assurance ingenuity and highly favorable economic climate, especially the low-cost, dedicated, and skilled labor force, to manufacture the product very cheaply in high volume
- Capture market share in the United States and Europe (and thus generate demand appropriate to the low-cost production volume) through aggressive pricing
- Gain dominance and ownership of the product by adding market-driven proprietary enhancements as experience is accumulated

In response, during the 1970s, U.S. electronics manufacturers began to move their production offshore to Taiwan and other Asian countries whose low-cost, highly skilled labor force and favorable economies ensured competitiveness with the Japanese.

In many of these countries, companies have evolved that have honed these manufacturing skills to a fine edge because of the huge production volumes they have run through their factories for U.S. companies. These companies have either learned or licensed the requisite product technologies to develop their own products and by now, have leveraged their high-volume production capabilities into formidable competition for their original U.S. customers.

Japan became the premier producer of consumer electronics in the early 1980s to the extent that the United States is all but out of that business now. RCA is an example of an early electronics innovator that no longer is a participant. South Korea became the offshore production site for Japan when Japanese costs rose; now South Korea is the premier producer of consumer electronics. From 1983 through 1985, Taiwan became the offshore production site for numerous U.S. PC clones and add-in boards; now Taiwan is a serious worldwide competitor in all aspects of the PC market. Similar examples exist for computer peripherals, such as disks, printers, terminals, and modems.

Where Is Electronic Equipment Produced Today?

North America is still the dominant producer of data processing, communications, and industrial electronic products, but the trend clearly indicates significant erosion of North American suppliers. When any electronic product, such as computers, communications devices, or industrial products, reach the commodity volume level, the U.S. economy and business climate are not in a good position to compete on an international scale with Japan and the Asian NICs. Therefore, more and more electronic equipment production—particularly high-volume production—will be done in Japan and the Asian NIC regions.

Although this trend has been going on since the 1970s, it accelerated between 1985 and 1986 when the U.S. worldwide production share fell from its 1984 level of 48 percent to 44 percent in 1986. The dramatic shift in power from U.S. suppliers to Japanese and Pacific Rim suppliers began with the 1984 boom market in the United States; it is continuing today. The following three major events occurred during the 1984 through 1988 period:

- The 1985 near recession
- The application of commodity supply rules by Japanese and Asian suppliers
- U.S. suppliers weakened and reduced

In order to understand where the production is today and appreciate where it will be tomorrow, a review of the 1984 through the 1988 events follows.

1984—A Year of Excessive Demand

All sectors of the U.S. economy were engaged in vigorous buying in 1984; it was a very good year. Capital spending was up 17.7 percent over 1983. Consumer spending was up 4.4 percent, and government spending was up more than 4.5 percent. Demand for all types of products was very high; electronic equipment was no exception. Among electronic products, demand was especially strong for personal computers, work group and small departmental computers, manufacturing systems, and communications systems. Consumer products such as TVs, VCRs, and home appliances were also in high demand.

Also by 1983 and 1984, a crowd of new North American companies emerged, manufacturing communications equipment, personal computers, PC peripherals, and related products. Many producers of such equipment from Japan, Taiwan, and Korea also were entering the U.S. market during this period.

During 1984, the beneficiaries of the buying spree were both domestic equipment producers and foreign importers. The extremely high dollar plus the indigenous superior productivity of Japanese and Asian ROW economies made their products very competitive in the United States.

U.S. Equipment Producers Flourish

In spite of their inferior competitiveness, U.S. equipment suppliers still did well because of the very high demand and the "newness" of many of the data processing and communications products. This was especially true of the PC product segment that was experiencing extraordinary demand. Many domestic producers were successfully gaining share of this "hypermarket." U.S. producers of PCs, small microprocessor-based systems, peripherals, and a variety of communications products experienced growth in 1984 ranging from 70 percent for PCs to 20 percent for communications equipment.

Market research forecasts during 1984 were extremely bullish for PCs and communications products. Many U.S. companies geared up for expanded production, and because DRAMs and some microprocessors were in short supply, ordered aggressively.

The Bubble Bursts

The situation was ripe for a fall. This started in early 1985 when U.S. capital spending growth fell off to only 6.7 percent in 1985 (and plummeted to a negative 4.5 percent growth in 1986). A sharp decline in demand for electronic equipment during 1985 and 1986 resulted.

U.S. Loses Numerous Equipment Producers

When U.S. demand fell off, U.S. equipment producers were unable to compensate for the reduced domestic demand by increasing their exports. They found themselves fundamentally unable to compete with Japanese and Asian/Pacific producers. The sharp reduction in U.S. equipment demand also put severe competitive pressure from Japanese and Asian producers on U.S. equipment producers in the U.S. market. (See Chapter 2 for a review of how Japanese and Asia/Pacific suppliers excelled by applying the basic rules of marketing commodity products.)

Many U.S. suppliers, unable to meet competitive pressure in a declining market, went out of business, were acquired by larger suppliers, or were acquired by Japanese, Asian, or European companies. The net result was that by the end of 1986, there were significantly fewer U.S. electronic equipment producers, and the foreign producers were all that much stronger.

Thus, because of their fundamental superior competitiveness, the Japanese and Asian ROW producers were less affected by the U.S. equipment demand decline. Not only were they effectively able to balance the reduced U.S. demand with sales to other markets, but they also increased their share of the declining U.S. market.

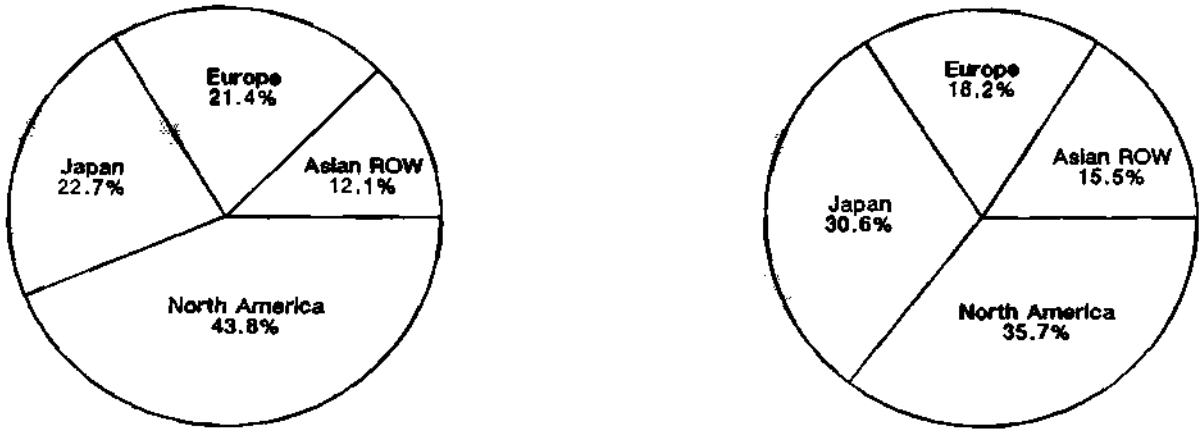
By mid-1987, the U.S. dollar, interest rates, and prices had fallen to the extent that the United States was extremely competitive. At that time, the United States commenced an export effort that has stimulated the U.S. economy in concert with all other regional economies (see Chapter 3). Worldwide capital spending and equipment demand surged. The result was the extraordinary recovery of electronic equipment production from 1985's low point through 1988.

During this dynamic recovery period, the replacement by foreign suppliers of the equipment producers shaken out by the 1985 recession and the offshore move by many U.S. producers contributed to a continuing but more gradual shift in electronic equipment production to Japan and the Asian ROW countries.

Figure 4-15 illustrate this production shift from North America to Japan and the Asian NICs. The North American share of electronic equipment production declined from 44.0 percent in 1984 to 36.0 percent in 1988, while Japanese and Asian NIC share climbed to 46.0 percent in 1988. European share of worldwide electronic production dropped from 21.4 percent in 1986 to barely 18.0 percent in 1988.

Figure 4-15

Regional Shares of Worldwide Electronics Production—1986 and 1988



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Source: Dataquest
September 1989

Electronic Equipment Production Forecast—1989 and 1990

The 1989 and 1990 Dataquest forecast for electronic equipment production is presented in Figures 4-16 through 4-21.

Three Strategic Issues Regarding Equipment Production

What Regional Production Shifts Will Occur During the Forecast Period?

North America. Dataquest forecasts that North American production will increase 7.6 percent in 1989 to $292 billion, down slightly from the 8.5 percent growth of 1988. The negative impact of the capital spending forecast is not expected to be as dramatic for production as for demand because of continued exports to Europe of computer, industrial, and communications products.

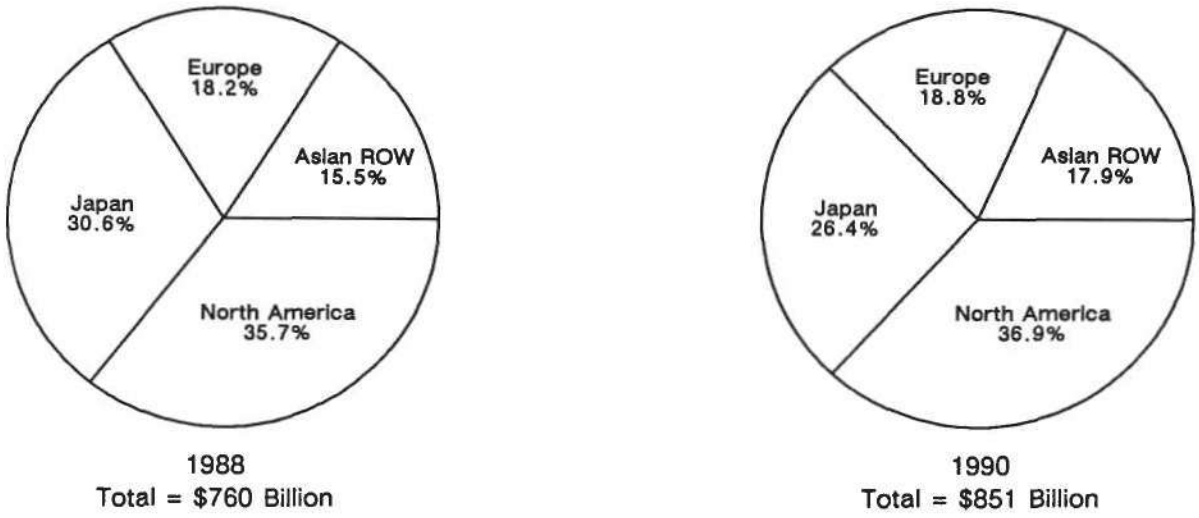
The data processing and communications segments are the only application markets that will show sizable growth—11 percent for both 1989 and 1990. The other market segments will remain flat or show small growth (see Table 4-4). Personal computers and workstations will drive the data processing segment growth; local area networks (LANs) and other data communications products will drive the communications segment. The LAN industry alone is forecast to grow more than 40 percent to about $3.6 billion in 1989.

Europe. The 1992 effect is the preparation by European, Japanese, Korean, and some U.S. companies for the single European market of 1992. Data processing, communications, and consumer product manufacturing will strengthen as companies build production facilities within the EEC. As in the United States, the data processing and communications markets are the only ones forecast to show double-digit growth through the forecast period.

Japan. Although the strong Japanese economy coupled with the import price benefits of the strong yen create a setting for strong domestic demand growth, Japanese electronic equipment production is not forecast to grow as rapidly as strong domestic demand. Given its forecast reduction in export growth, its increased growth of imports, and its increased offshore production in Asian ROW countries, Europe, and the United States, Japan's domestic equipment production will grow at about the same rate as that of the United States.

Figure 4-16

Regional Shares of Worldwide Electronic Equipment Production—1988-1990



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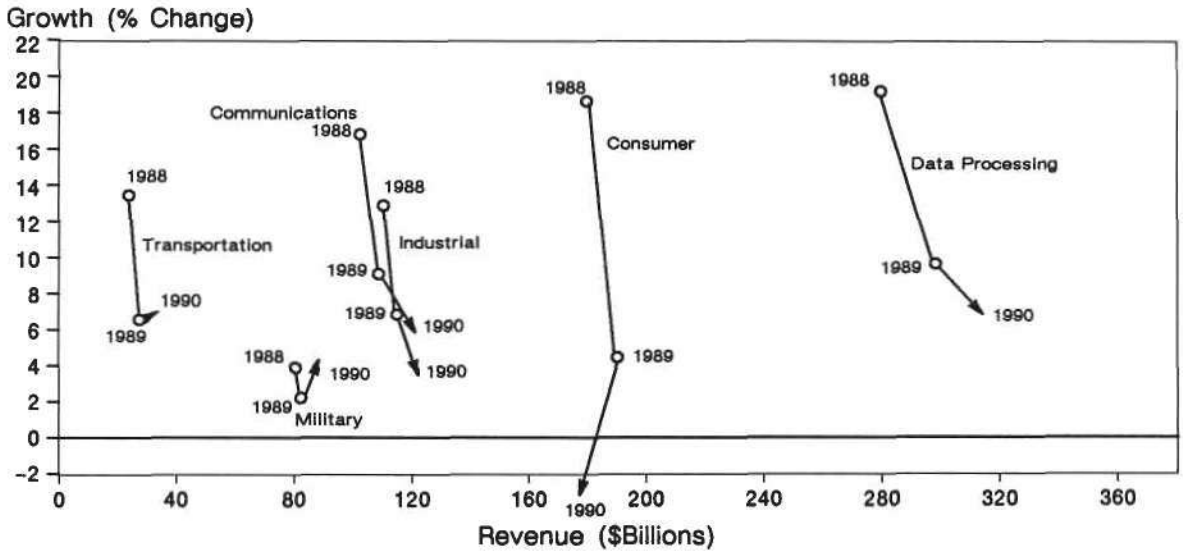
Source: Dataquest
September 1989

Figure 4-17

Growth Trends for Application Segments—Worldwide



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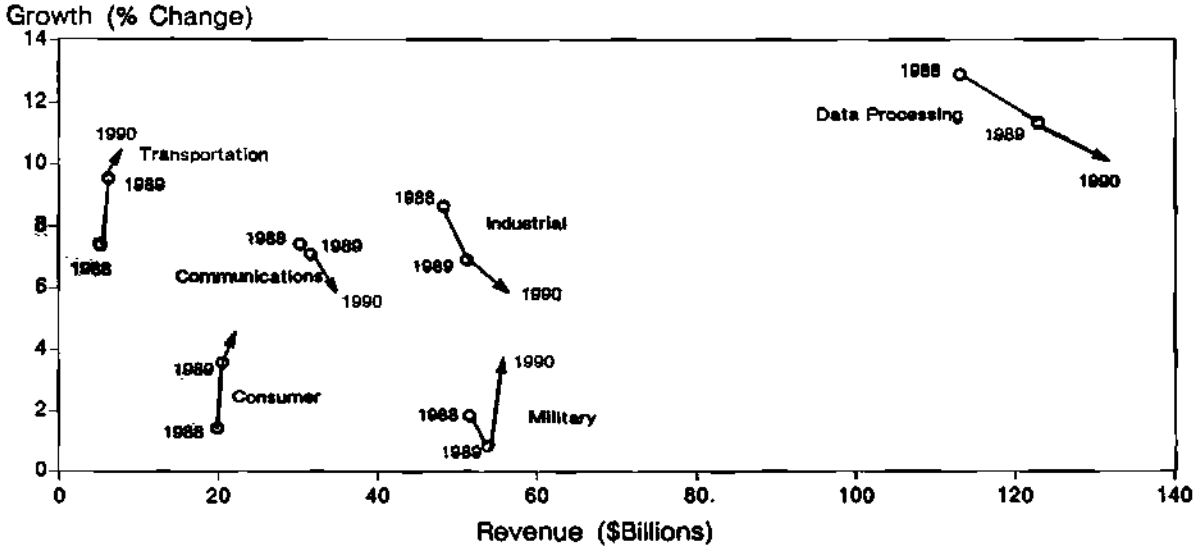
Source: Dataquest
September 1989

Figure 4-18

Growth Trends for Application Segments—North America



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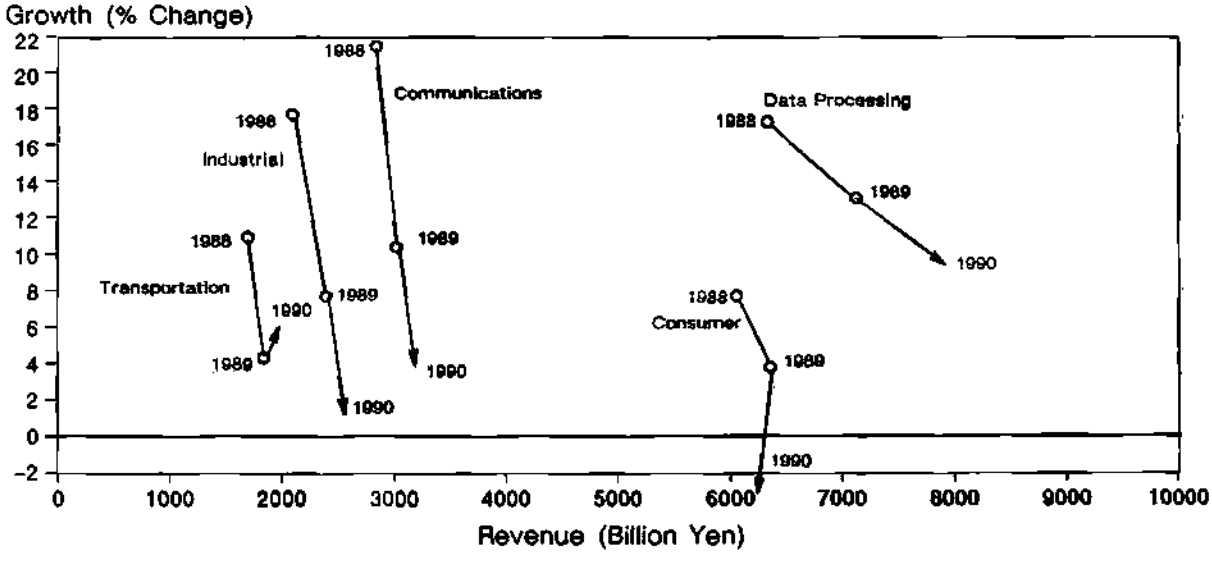
Source: Dataquest
September 1989

Figure 4-19

Growth Trends for Application Segments—Japan



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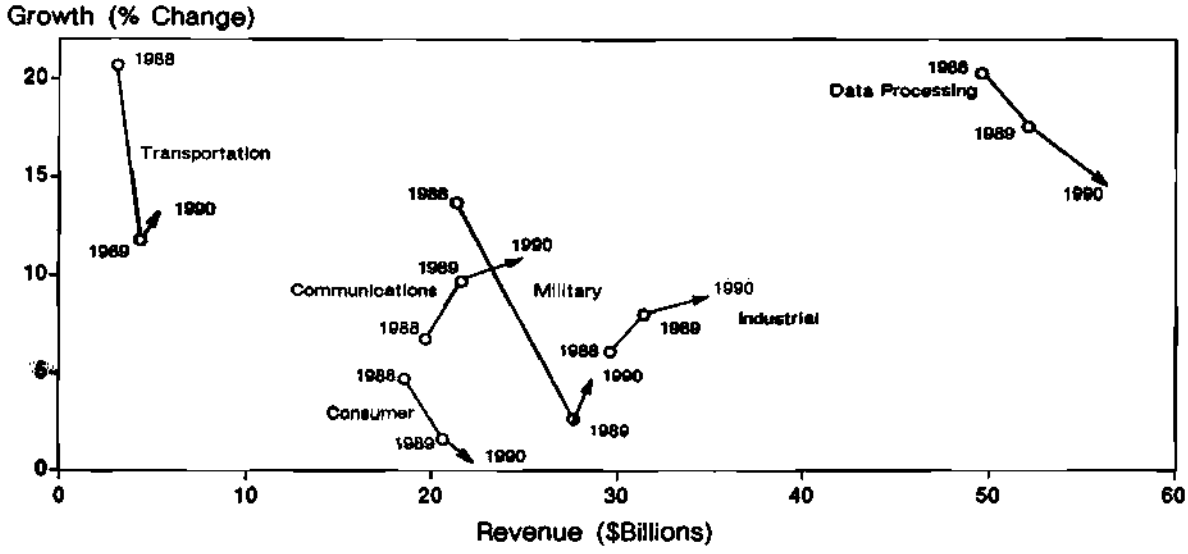
Source: Dataquest
September 1989

Figure 4-20

Growth Trends for Application Segments—Europe



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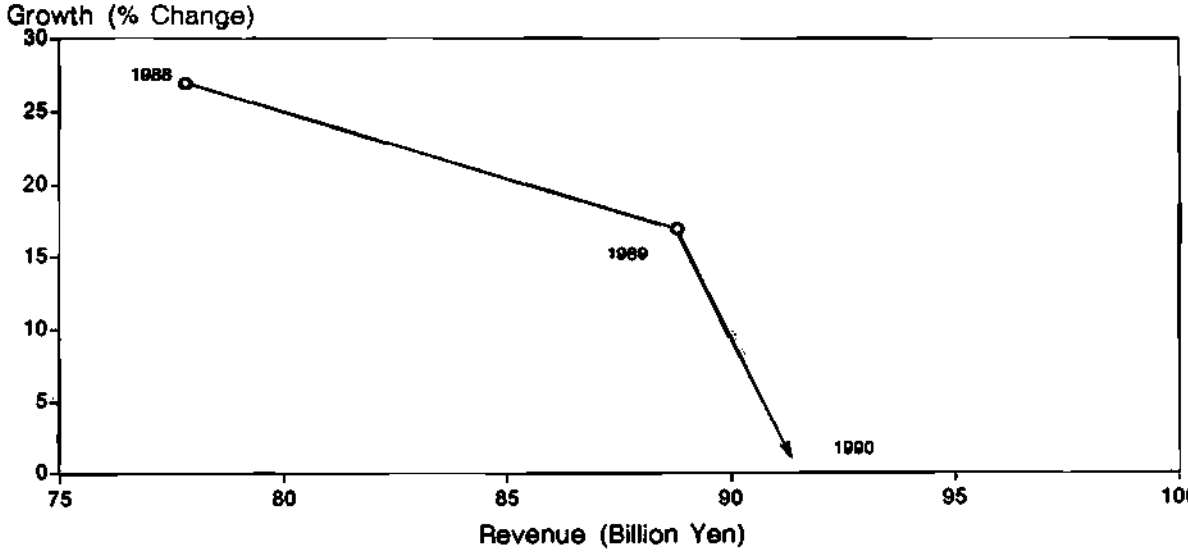
Source: Dataquest
September 1989

Figure 4-21

Electronic Equipment Growth Trends—Asian ROW



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Source: Dataquest
September 1989

Table 4-4

North American Electronic Equipment Production
History and Forecast—1988-1990
(Millions of Dollars)

Segment	1988	1989	1990	CAGR 1988-1990
Data Processing				
Computers	71,864	80,470	91,629	12.9%
Data Storage Subsystems	24,842	29,339	31,401	12.4%
Data Terminals	4,621	4,416	4,133	(5.4%)
Input/Output	10,600	11,038	11,170	2.7%
Dedicated Systems	5,506	5,399	5,186	(2.9%)
Subtotal	117,434	130,662	143,519	10.5%
Communications				
Customer Premises	11,359	12,896	14,014	11.1%
Public Telecommunications	7,313	7,535	7,909	4.0%
Radio	6,008	6,196	6,435	3.5%
Broadcast & Studio	1,690	1,771	1,871	5.2%
Other	2,010	2,106	2,202	4.7%
Subtotal	28,380	30,504	32,430	6.9%
Industrial				
Security/Energy Management	2,380	2,462	2,574	4.0%
Manufacturing Systems	15,874	16,832	17,685	5.6%
Instrumentation	7,702	8,378	8,796	6.9%
Medical Equipment	5,785	6,117	6,485	5.9%
Civil Aerospace	6,994	7,686	8,344	9.2%
Other	5,131	5,514	5,875	7.0%
Subtotal	43,866	46,990	49,759	6.5%
Consumer				
Audio	299	320	339	6.5%
Video	5,079	5,262	5,547	4.5%
Personal Electronics	845	881	913	3.9%
Appliances	10,906	11,185	11,497	2.7%
Other	1,165	1,215	1,264	4.2%
Subtotal	18,294	18,863	19,560	3.4%
Military	52,345	52,968	55,348	2.8%
Transportation	10,964	12,042	13,281	10.1%
Total	271,282	292,029	313,897	7.6%

Source: Dataquest
September 1989

Asian ROW. Asian ROW electronic production should be the fastest growing of all four major regions through the forecast period, partly because Japan and the United States have been shifting production to this region. This growth also is driven by consumer products, PC clones, and related products. Asian ROW consumer production is forecast to increase 21 percent in 1989; data processing should increase 14 percent. The Asian ROW telecommunications segment is growing rapidly, but to date it is still a relatively small share of total production.

The consumer product segment is expected to undergo such dramatic growth because of the huge potential demand from regions just beginning to open their markets to consumer product imports. Vast markets such as China and Thailand represent massive potential to Asian ROW producers as well as to Japanese-based companies that have built production facilities in this region.

What Are the Regional Imbalances between Demand and Production?

The most significant strategic issue embodied in the electronic equipment forecast is the erosion of the electronic equipment power base from the United States to Japan and the Pacific Rim countries. Table 4-5 compares the regional demand for electronic equipment with regional production and assumes that total demand equals total production.

Table 4-5 makes it clear that in 1988, Japan and the Asian ROW countries supplied more than 46 percent of electronic equipment worldwide, up from 35 percent in 1986. However, the forecast through 1990 shows that the Japanese share is expected to decline from 31 percent in 1988 to 26 percent in 1990 for the reasons discussed previously. Japan's indigenous competitiveness is declining as it expands its economy to approach that of a world economic power; it too must transplant production to more competitive countries to remain competitive.

Thus as European demand share decreases slightly over the period, U.S. and Japanese companies will compete with the European companies by producing within Europe or exporting from the United States. This will have the effect of a slight increase in European production share to 18.8 percent through 1990 (see Table 4-5).

Japanese and Asian ROW companies will supply the growing Japanese and Asian demand from production that is shifting increasingly away from Japan toward the Asian countries. Expanding demand from China will also be supplied from the increasing production within the Asian ROW region.

What Will Each Region Spend on Semiconductors?

Table 4-6 shows the semiconductor demand and forecast by region. The worldwide projections for semiconductor demand (expenditures), also shown in Table 4-6, are expected to grow through the first half of 1989, then decline as the electronic equipment production declines. Overall 1989 semiconductor demand growth is forecast to be 15.2 percent followed by a 0.6 percent decline in 1990. The merchant market is expected to reach $58.2 billion in 1989 and to decline to $57.9 billion in 1990.

Table 4-5

Regional Imbalances in Electronic Equipment Production and Demand—1986, 1988, 1990

1986

Region	Demand ($B)	Demand Percent	Net Exports ($B)	Net Exports Percent	Production ($B)	Production Percent	Ratio of Production to Demand
North America	$214	40.5%	$17	3.2%	$231	43.8%	107.9%
Europe	178	33.7	($65)	(12.3%)	113	21.4	63.5%
Japan	86	16.3	$34	6.4%	120	22.7	139.5%
Asian ROW	50	9.5	$14	2.7%	64	12.1	128.0%
	$528	100.0%	0	0	$528	100.0%	

(Continued)

Table 4-5 (Continued)

Regional Imbalances in Electronic Equipment Production and Demand—1986, 1988, 1990

1988

Region	Demand ($B)	Demand Percent	Net Exports ($B)	Net Exports Percent	Production ($B)	Production Percent	Ratio of Production to Demand
North America	$302	39.7%	($ 31)	(4.1%)	$271	35.7%	89.7%
Europe	253	33.3	($115)	(15.1%)	138	18.2	54.5%
Japan	131	17.2	$102	13.4%	233	30.7	177.9%
Asian ROW	74	9.7	$ 44	5.8%	118	15.5	159.5%
	$760	100.0%	0	0	$760	100.0%	

1990

Region	Demand ($B)	Demand Percent	Net Exports ($B)	Net Exports Percent	Production ($B)	Production Percent	Ratio of Production to Demand
North America	$331	38.9%	($ 17)	(2.0%)	$314	36.9%	94.9%
Europe	280	32.9	($120)	(14.1%)	160	18.8	57.1%
Japan	153	18.0	$ 72	8.5%	225	26.4	147.1%
Asian ROW	87	10.2	$ 65	7.6%	152	17.9	174.7%
	$851	100.0%	0	0	$851	100.0%	

Source: M. Ford and B. Hesley

Table 4-6

Worldwide Semiconductor Demand and Demand Share by Region—1988-1990 (Billions of Dollars and Percent Share)

Region	Demand ($B) 1988	Demand ($B) 1989	Demand ($B) 1990	Demand Share (%) 1988	Demand Share (%) 1989	Demand Share (%) 1990
North America	$16.0	$18.3	$17.6	31.7%	31.4%	30.4%
Europe	8.5	9.4	9.6	16.8	16.2	16.6
Japan	20.3	23.4	23.1	40.2	40.2	39.9
ROW	5.7	7.1	7.6	11.3	12.2	13.1
Total	$50.5	$58.2	$57.9	100.0%	100.0%	100.0%

Source: Dataquest September 1989

CHAPTER 5

Semiconductor Demand

In 1988, more than $50 billion worth of semiconductor products were consumed worldwide. This demand constituted 32 percent annual growth, the third highest annual growth recorded since 1970. Only the 50 percent growth in 1973 and the 45 percent in 1984 were higher.

The record growth in 1988 followed three years of sustained growth after the 1985 recession, in which merchant demand was only $24 billion. This sustained growth was truly extraordinary, reflecting a doubling of semiconductor demand in only three years for a CAGR of 28 percent.

Even though semiconductor demand and production represent the next step down the waterfall of demand (see Figure 5-1), this chapter focuses only on semiconductor demand; Chapter 6 focuses on semiconductor production. This chapter describes the underlying forces that drove semiconductor demand and sustained the extraordinary growth from 1986 to 1988; it also provides the forecast for 1989 and 1990. The chapter contains the following three sections:

- Background—The underlying forces of demand are addressed as follows:
  - Reasons for sustained growth—What has caused the sustained growth in demand over the last three years?
  - Semiconductor producers—Who is satisfying the demand?
  - Demand sources—Where is the demand being generated?
    - Equipment market segments
    - Semiconductor products
    - Geographical regions
- Demand forecast—1989 through 1990 worldwide and regional demand forecast by product type and electronic end-application market, including the economic and end-product demand drivers
- Strategic issues—Key issues relating to the semiconductor demand

Background

Reasons for Sustained Growth—1985 through 1988

Primarily, semiconductor demand growth is a function of equipment production growth. It is assumed that on a worldwide basis, equipment production equals equipment demand, and equipment demand growth is driven by capital spending growth. Figure 5-2 shows the historical correlation between the annual growth of worldwide capital spending, electronic equipment production, and semiconductor consumption for the period from 1970 through 1988. Examination of Figure 5-2 shows that the major contributor to the sustained growth of electronic equipment production was the dynamic growth in worldwide capital spending during 1987 and 1988.

The resulting if-sold values of worldwide electronic equipment production and the corresponding semiconductor consumption from 1985 through 1988 are shown in Table 5-1 along with their respective CAGRs. As the table shows, electronic equipment production has increased 66 percent from its 1985 level, to more than $760 billion in 1988, a 1985 through 1988 CAGR of more than 19 percent. Semiconductor consumption, including captive consumption (defined herein), has doubled its 1985 recession level for a CAGR of 26 percent to more than $54 billion in the same period.

Secondarily, the sustained growth in semiconductor demand is from increased semiconductor pervasiveness—particularly in those equipment market (application) segments that represent the highest electronic equipment volume and most rapid growth. Table 5-1 shows that the semiconductor

demand value was 6 percent of the electronic equipment value in 1985, which increased to more than 7 percent by 1988.

Semiconductor Producers

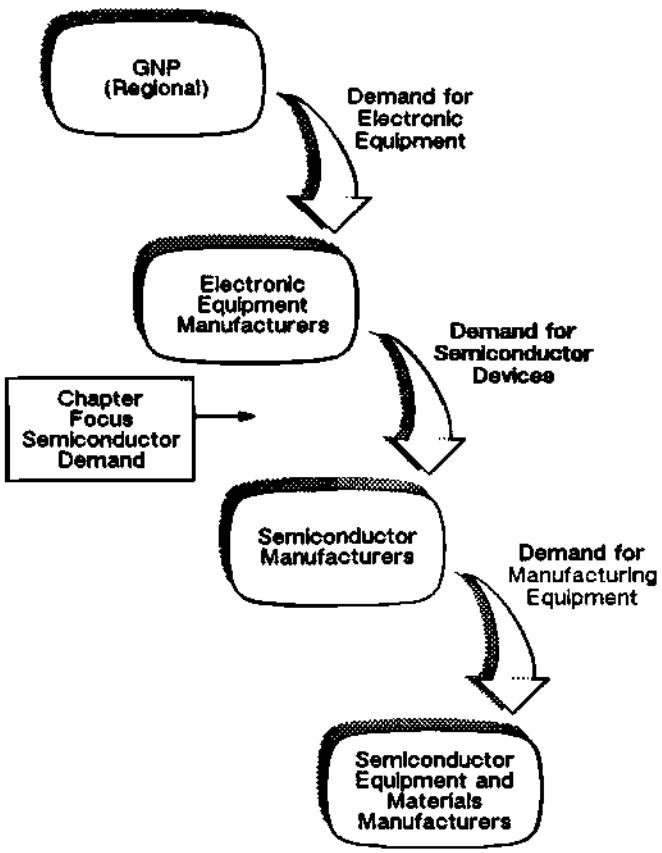
Because semiconductor manufacturers supply their products to electronic equipment producers, within any region, the level of demand for semiconductor products is created by the level of electronic equipment production. More than 200 companies throughout the world supply their products to electronic equipment producers. These companies can be characterized into one of the following three broad classifications:

- Independent manufacturer
- Division (of a larger corporation) manufacturer
- Captive manufacturer

The first two of these classifications, both of which are merchant suppliers, compete in the worldwide merchant market to supply semiconductor products to manufacturers of electronic equipment worldwide. The third classification—captive—supplies products only for internal consumption to satisfy its own electronic equipment production requirements. These three types of manufacturing companies will be discussed in more detail in Chapter 6. It is important to note that the distinction between merchant and captive suppliers is more prevalent in the United States than in Japan, where most semiconductor production is integrated into a larger electronics company.

Figure 5-1

Waterfall of Demand



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Source: B. Hesley & M. Ford

Figure 5-2

Comparison of Worldwide Capital Spending, Electronic Equipment Production, and Semiconductor Demand Growth Rates—1970-1988

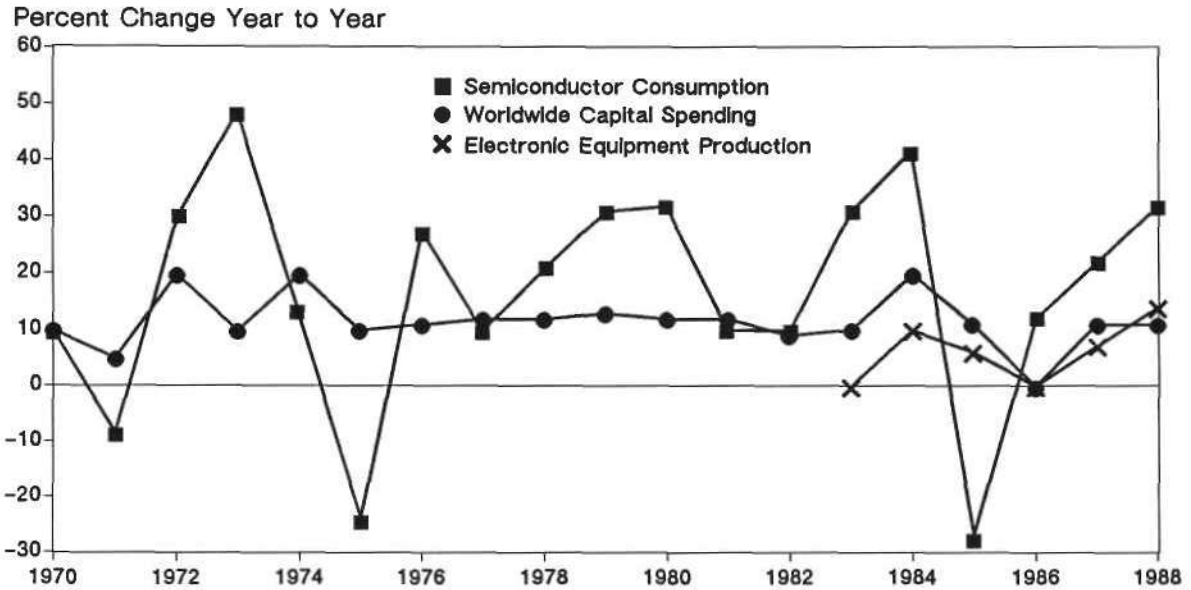


Table 5-1

Worldwide Electronic Equipment and Semiconductor Demand—1985-1988

	1985	1986	1987	1988	CAGR 1985-1988
Electronic Equipment Production	$455.9	$528.8	$650.8	$760.0	18.6%
Semiconductor Demand	$ 27.4	$ 32.8	$ 39.9	$ 54.8	26.0%
Pervasiveness	6.0%	6.2%	6.1%	7.2%	

Note: Includes captive suppliers

Source: Dataquest
September 1989

Semiconductor Demand Sources

Semiconductor demand can be viewed in the following three ways:

- Demand generated by the individual equipment market application segments
- Demand generated for semiconductor product types
- Demand generated within a geographic region

Equipment Market Segments

Because electronic equipment production creates semiconductor demand, the volume and growth of semiconductor demand by electronic equipment application markets is fundamental to understanding sources of demand growth. The appli-

cation market segments of electronic equipment production, as defined in Chapter 4, are as follows:

- Data processing
- Communications
- Industrial
- Consumer
- Military
- Transportation

Within the electronic equipment market, the highest growth markets were identified in Chapter 4 to be the data processing, communications, and consumer segments. Figure 5-3 depicts the worldwide electronic equipment market, and Figure 5-4 depicts the resulting semiconductor consumption by electronic equipment market segments for 1986 through 1988. Not surprisingly, the segments with the highest demand and demand growth were the data processing, consumer, and communications segments, and these were also the highest-volume and highest-growth segments of semiconductor demand.

Figure 5-5 shows the degree of semiconductor pervasiveness as measured by the percentage of electronic equipment volume represented by semiconductor consumption. The transportation, communications, and data processing segments show the highest level of pervasiveness. However, the data processing, consumer, and military segments show the highest growth in pervasiveness.

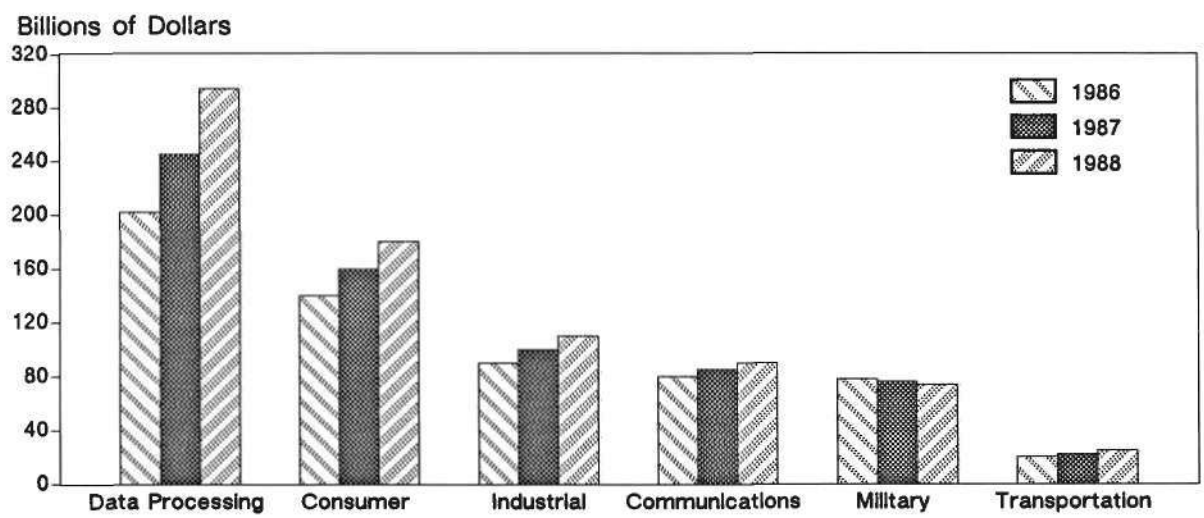
The three segments driving the sustained growth of semiconductor demand can therefore be characterized as follows:

- Data processing equipment segment—highest demand, highest demand growth, and most rapid growth in semiconductor pervasiveness
- Consumer equipment segment—second highest demand, third highest demand growth, and second fastest growth in pervasiveness
- Communications equipment segment—fourth highest demand, second highest demand growth, and second highest in pervasiveness

In Figure 5-4, it can be seen that more than two-thirds of the 1988 worldwide semiconductor consumption ($35 billion) has been by producers of data processing, consumer, or communications products. Consumption of semiconductors by these producers has experienced a CAGR of more than 22 percent from 1985 through 1988.

Figure 5-3

Worldwide Electronic Equipment Market by Application Market Segment—1986-1988



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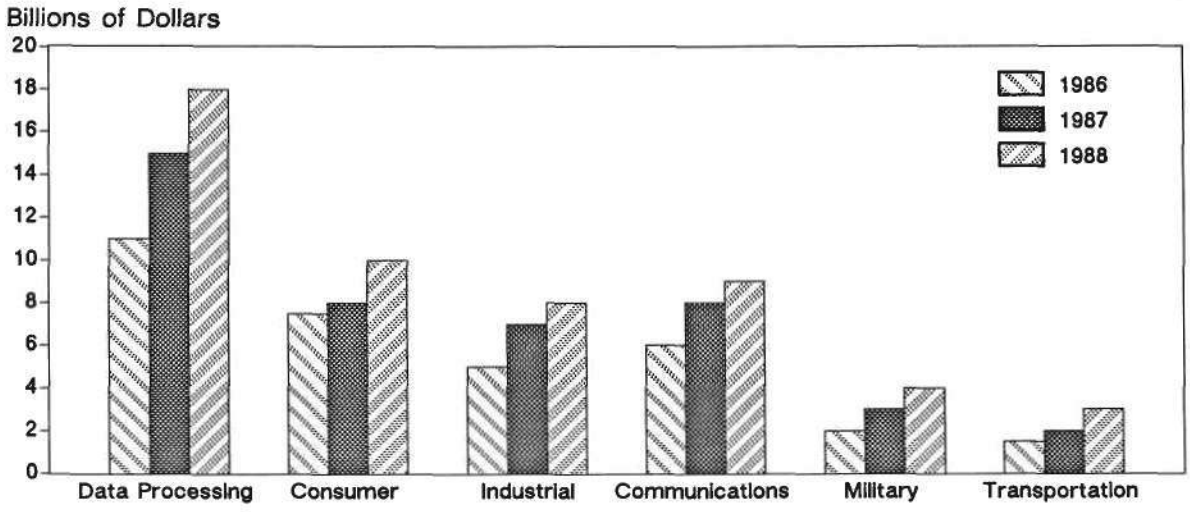
Source: Dataquest
September 1989

Figure 5-4

Worldwide Semiconductor Demand by Application Market Segment—1986-1988



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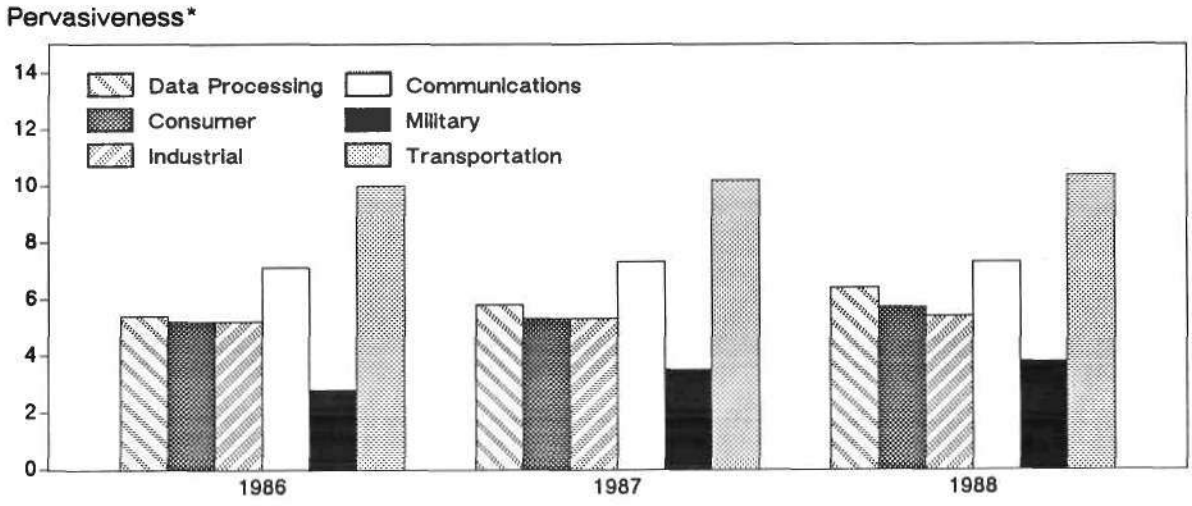
Source: Dataquest September 1989

Figure 5-5

Worldwide Pervasiveness by Electronics Segment—1986-1988



*Semiconductor Consumption as a Percent of Equipment Volume

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Source: Dataquest September 1989

Semiconductor Products

In response to semiconductor demand, the semiconductor industry supplies billions of semiconductor devices to electronic equipment producers worldwide. These devices consist of many different types of products, including diodes, transistors, ICs, and optoelectronic devices. Dataquest classifies these products into the following major categories:

- ICs
- Discrete devices

Discrete Devices. Discrete devices comprise many types of individual transistors, diodes, and switching devices, such as silicon control rectifiers (SCRs). They perform widely diverse tasks.

ICs. An integrated circuit is a single chip that contains more than one active device. For example, it may have a number of transistors, diodes, resistors, or capacitors as part of an electronic circuit. Integrated circuits vary widely by function. They can perform digital or linear electronic functions and may be based on a number of basic technologies, such as bipolar or MOS.

Dataquest further classifies ICs into memory, microdevices, logic, and linear. These categories are described in the following paragraphs with some examples of commercially available product types.

Memory ICs. Memory ICs are designed for the storage and retrieval of binary information. Random-access memory (RAM), allows storage and retrieval of information created by the user. When such information is retained only as long as power is supplied to the RAM, the memory device is referred to as "volatile." Examples of volatile RAM products are the following:

- DRAMs
- Static RAMs (SRAMs)
- Hierarchical RAMs (HRAMs)

Examples of nonvolatile memory products, which do not lose information when power is removed, are the following:

- Read-only memory (ROM)
- Programmable read-only memory (PROM)
- Erasable PROM (EPROM)
- Electrically erasable PROM (EEPROM)

Microdevices. Microdevices are further categorized into microprocessors, microcontrollers, and microperipherals, as follows:

- Microprocessor—A microprocessor can be a single chip or a collection of chips that function together as the central processing unit (CPU) of a system.
- Microcontroller—A microcontroller is an IC containing a CPU, memory, and input/output (I/O) capability, and can perform all the basic functions of a computer.
- Microperipherals—Microperipherals are support devices for microprocessors or microcontrollers. They either interface external equipment or provide system support. Examples are as follows:
  - Disk-drive controllers
  - Cathode-ray tube (CRT) controllers
  - Graphics chips
  - Bus controllers
  - Serial and parallel I/O chips

Logic Devices. Logic may be visualized as the "glue" that surrounds the IC devices discussed above. They handle digital signals in a variety of ways: routing, multiplexing, demultiplexing, encoding/decoding, counting, and comparing. Logic devices also are used to implement I/O interfaces. They are divided into two categories: standard and ASIC, shown as follows:

- Standard logic—Standard logic ICs are readily available off the shelf from a number of suppliers. They come in predefined logical functions in a variety of arrangements. Examples of standard logic types are as follows:
  - Transistor-transistor logic (TTL)
  - Emitter-coupled logic (ECL)
  - Metal-oxide semiconductor (MOS)
- ASICs—ASICs are integrated circuits designed or adapted by the user for a specific application or set of logical functions. Examples of ASIC types are as follows:
  - Programmable logic devices (PLDs)
  - Gate arrays
  - Cell-based design
  - Full-custom design

Semiconductor Demand by Product—1987 through 1988

The worldwide semiconductor demand and demand growth by product category is shown in Table 5-2. The major category with the highest 1987 through 1988 CAGR is that of ICs, with a CAGR of 37 percent, whereas the other major categories experienced growth of 27 percent or less. ICs also represent more than 80 percent of total product consumption. Table 5-2 excludes consumption by captive producers and thus considers only the consumption of products from merchant suppliers.

Within the IC category, both the highest-volume and the highest-growth products are MOS digital products, with a CAGR of 54.3 percent. MOS digital products represent slightly more than half (53.0 percent) of total semiconductor consumption. Within this category, MOS memories show a CAGR of 92.3 percent, whereas MOS microdevices and logic experienced a CAGR of 40.1 percent and 29.2 percent, respectively. MOS memories represent nearly 23.0 percent of total semiconductor consumption, whereas microdevices and logic together represent more than 30.0 percent.

Table 5-3 lists the top 10 semiconductor products in terms of annual growth in 1988 over 1987. These 10 products represent 44.0 percent of the 1988 total demand and had an aggregate annual growth of 62.4 percent in 1988 over 1987. The remaining 56.0 percent of the 1988 demand grew only 15.0 percent over 1987.

Table 5-2

Worldwide Semiconductor Consumption—1987-1988
(Millions of Dollars)

	1987	1988	Growth 1987-1988
Total Semiconductor	$38,278	$50,859	32.9%
Total IC	$29,904	$41,068	37.3%
Bipolar Digital	$ 4,762	$ 5,200	9.2%
Memory	621	689	11.0%
Logic	4,141	4,511	8.9%
MOS Digital	$17,488	$26,988	54.3%
Memory	6,081	11,692	92.3%
Micro	5,099	7,144	40.1%
Logic	6,308	8,152	29.2%
Linear	$ 7,654	$ 8,880	16.0%
Total Discrete	$ 6,665	$ 7,612	14.2%
Total Optoelectronic	$ 1,709	$ 2,179	27.5%

Note: Some columns may not add to totals shown because of rounding.

Source: Dataquest
September 1989

Table 5-3

Top 10 Demand Growth Semiconductor Products
1988 over 1987

Product	Annual Growth	1988 Demand (Billions of Dollars)	Percent of Total 1988 Revenue
MOS DRAM Memory	121.0%	$ 6,417	12.7%
MOS ASIC—PLD	94.0%	150	0.3%
MOS Microperipherals	79.0%	2,404	4.8%
MOS SRAM Memory	79.0%	2,173	4.3%
MOS EPROMs	50.0%	2,917	5.8%
MOS Microprocessors	47.9%	1,755	3.5%
Bipolar ASIC—PLD	43.0%	529	1.0%
MOS ASIC—Cell-Based	41.0%	1,083	2.1%
MOS ASIC—Gate Arrays	38.6%	1,947	3.9%
MOS Microcontrollers	38.0%	2,799	5.5%
Total	62.4%	$22,174	43.9%
All Other Products	15.0%	$28,319	56.1%

Note: Excludes captive demand

Source: Dataquest
September 1989

The electronic equipment products driving the demand for these highest-growth semiconductor products are PCs, small-scale computers, technical workstations, graphics workstations, personal peripherals such as disks and small laser printers, and LANs that tie all of these desktop systems together.

The demand for MOS DRAM memories, fast 32-bit microprocessors, ASICs, and other MOS microdevices grew so rapidly during late 1987 and early 1988 that a serious supply shortage existed. Although this supply shortage has eased somewhat in 1989, latent demand for these products is expected to stimulate their continued buoyant growth through mid-1989. The 1989 and 1990 demand forecast for these products appears in the subsection entitled "Semiconductor Demand Forecast—1989 and 1990."

The shortage of DRAMs and SRAMs, and the associated price inflation of these devices, has had a substantial impact on both the magnitude of the overall semiconductor demand growth and the role that MOS digital products have in the semiconductor industry. DRAMs make up so much of the semiconductor sales volume that variations in their price can inflate or deflate the overall industry sales volume, causing distorted views of growth or decline.

MOS Memory

The "Swing Vote" in the Semiconductor Industry

DRAMs make up so much of the semiconductor sales volume that they have become the "swing vote" in determining the health of the industry. In fact, DRAM prices can have a monumental impact on the overall industry sales volume and result in skewed growth or decline numbers.

During 1984, the Japanese production capacity for MOS memory expanded voraciously as the perceived PC boom appeared to be creating a huge demand for 64K DRAMs. When the bubble burst in 1985, the Japanese producers continued their high-volume production, and the supply far exceeded the demand. The 256K part also was coming onstream at that time, and the Japanese producers were anxious to push this more profitable part. Triggered by rapid price slashing, first by Micron in the United States and then by various Japanese suppliers, the price of both 64K

and 256K devices plummeted during 1985 and 1986.

Faced with severe unprofitability, the major remaining U.S. DRAM producers, with the exception of Micron and TI, withdrew from the market. The U.S. producers, through the Semiconductor Industry Association (SIA), succeeded in gaining U.S. government support for their accusation that the Japanese were "dumping" 64K devices (i.e., selling them at prices well below cost).

This resulted in the U.S.-Japan Semiconductor Trade Arrangement of 1986, which required that Japan not participate in the practice of dumping and that Japan's Ministry of Trade and Industry (MITI) manage the Japanese production to balance supply with demand to force the DRAM prices to stabilize so that U.S. producers could compete. It is interesting to note that when the DRAM prices were stabilized by raising prices, the effect was to generate huge additional profits for Japanese producers to reinvest in new technology. The other major element of the agreement was that Japan would actively assist the U.S. producers in obtaining at least a 20 percent share of its market for semiconductors.

The results of this agreement were questionable, at best. MITI reduced production of DRAMs through most of 1987, demand recovered as U.S. and global economies heated up, and by mid-1987, demand far exceeded supply and the prices of DRAMs and SRAMs were uncharacteristically high.

Perhaps the best result of this agreement was the development of long-term buyer-seller agreements and dialogue that were designed to prevent the recurrence of the 1984 disaster. The objective of this new procurement-supply process was to supply and adhere to long-term forecasts on both sides of the table, thus stabilizing both the buyers' inventory control and the vendors' production scheduling.

As the PC boom of late 1987 and 1988 moderated in early 1989 and MITI has advised higher production levels, the supply of MOS memories balanced demand within the first two quarters of 1989. At that time, a considerable decline in memory prices could occur, which will amplify the perceived decline in semiconductor demand through 1989 and 1990 just as the inflated pricing of DRAMs in 1987 and 1988 inflated the extraordinary growth during that period.

Semiconductor Demand by Region—1984 through 1988

The worldwide semiconductor demand by region for merchant sales only is shown in Table 5-4. This table illustrates that the combined demand from the Japanese and Asian ROW regions was $26.5 billion in 1988, or 52.0 percent of the 1988 total demand. The North American demand was nearly $16.0 billion or 31.2 percent of the total. The 1984 figures are quite different. In 1984—only four years earlier—Japan and the Asian ROW represented $11.0 billion, or only 38.0 percent of the $29.0 billion total, whereas the North American demand was $13.0 billion for a 45.0 percent share. This is consistent with the numbers in Table 4-2, which show that the 1984 North American demand for electronic equipment constituted 44.0 percent of the worldwide demand, whereas the Japanese and ROW regions' combined share was only 21.0 percent. By 1988, the North American equipment demand fell to 40.0 percent, while the Japanese and Asian ROW share climbed to 27.0 percent.

Although the North American region has declined somewhat since 1984 as a consumer of electronic equipment relative to Japan and Asian ROW countries, its share of electronic production has fallen much further, as indicated by the decline in semiconductor demand share from 45.0 percent to 31.2 percent. This sharp decline in North America's share of semiconductor consumption is discussed further in the subsection entitled "What Caused the Regional Shift in Worldwide Semiconductor Demand from 1984 through 1988?"

Semiconductor Demand Forecast—1989 and 1990

The worldwide economic outlook developed in Chapter 3 calls for a deceleration of growth of real GNP/GDP starting in mid-1989 and continuing through mid-1990. Beyond 1990, a healthy recovery period is forecast. The impact of this deceleration in capital spending, electronic equipment production, and semiconductor demand growth worldwide is shown in Figure 5-6. The specific impact of this reduced capital spending on worldwide equipment production by application market was discussed in Chapter 4 and is reviewed in Figure 5-7.

Although electronic equipment production growth is forecast to remain positive through 1989 and 1990, its overall annual growth rate and those of all application segments will be less than one-half of what they were in 1988. Figure 5-6 also forecasts the resulting worldwide demand for semiconductors to grow 12.3 percent in 1989, or less than one-half the 1988 rate, and to decline 2.4 percent in 1990.

Table 5-4

Regional Semiconductor Consumption—1987-1988
(Millions of Dollars)

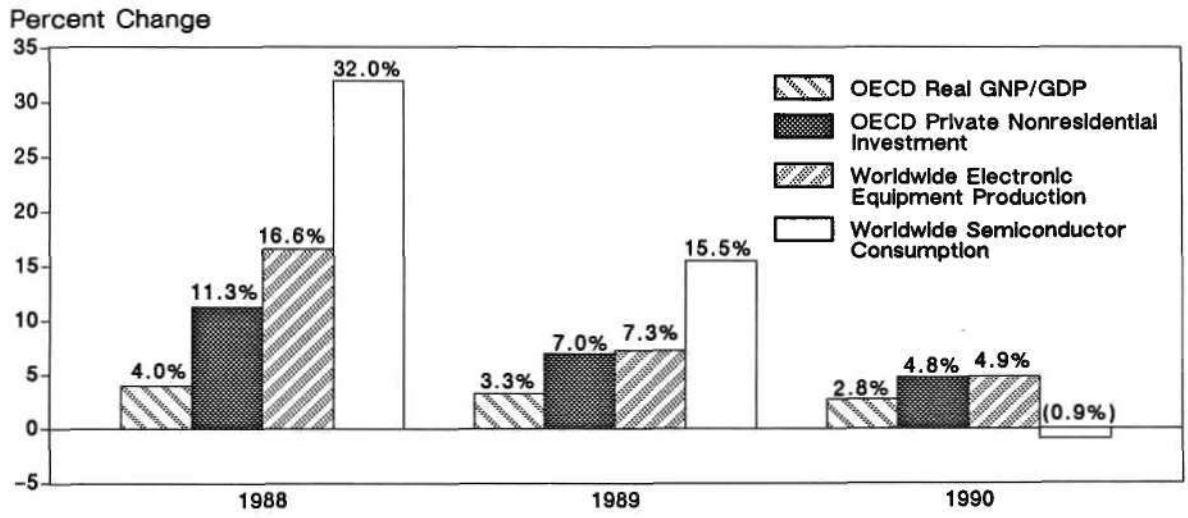
Region	1987	1988	Percent Share 1988	Growth 1987-1988
North America	$12,845	$15,844	31.2%	23.3%
Japan	14,992	20,772	40.8	38.6%
Europe	6,480	8,491	16.7	31.0%
Asian ROW	3,961	5,752	11.3	45.2%
Total	$38,278	$50,859	100.0%	32.9%
Annual Growth	24.1%	32.9%		

Note: Excludes captive demand

Source: Dataquest
September 1989

Figure 5-6

Estimated Changes in Economic, Electronic Equipment and Economic and Semiconductor Demand Growth—1988-1990



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Source: Dataquest
September 1989

Figure 5-7

Worldwide Electronic Equipment Production Outlook

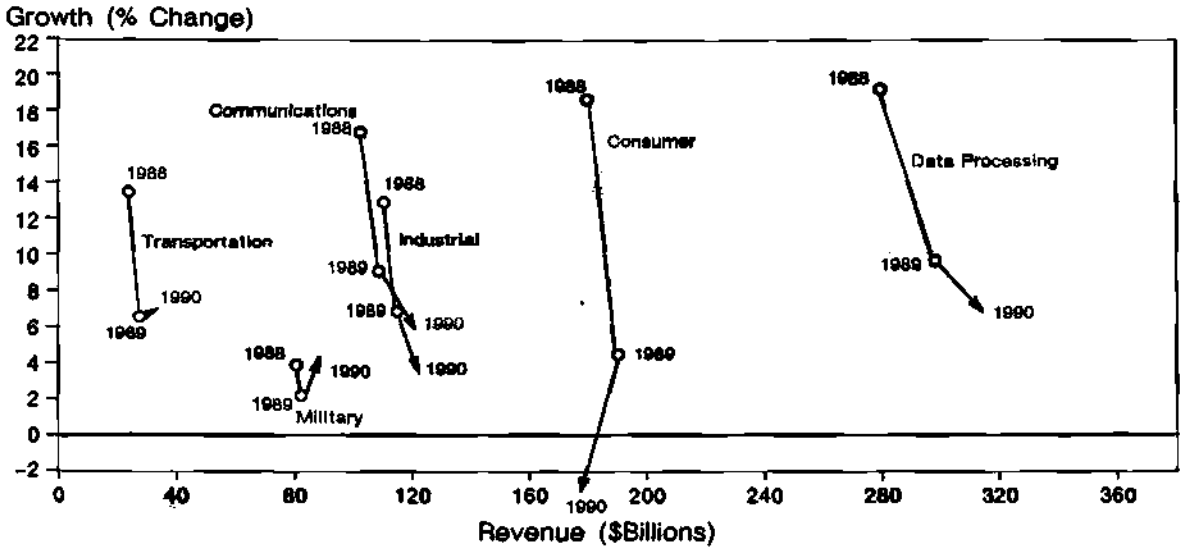
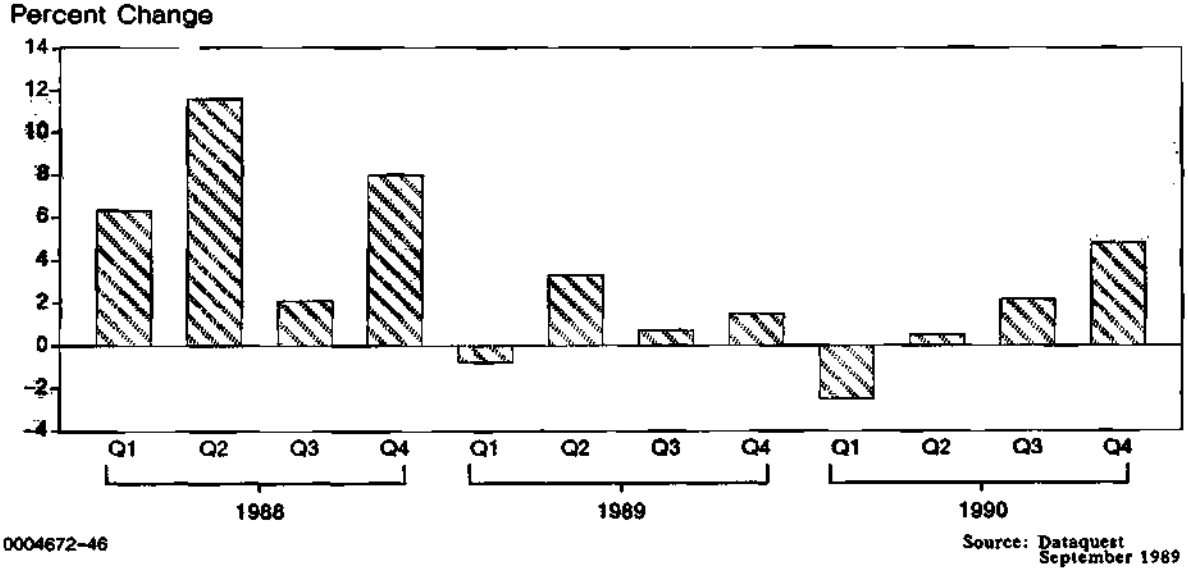


Figure 5-8

Quarterly Worldwide Semiconductor Demand Forecast—1989-1990



Worldwide Semiconductor Quarterly Demand Forecast 1989-1990

The worldwide semiconductor demand forecast is shown on a quarterly basis for 1989 and 1990 in Figure 5-8. Given the economic outlook expressed in Figure 5-6, and first-quarter 1989 growth of negative 0.8 percent, followed by second-quarter growth of 3.3 percent, Dataquest estimates only 0.7 percent and 1.5 percent quarterly growth for the remainder of 1989. This growth will be fueled by MOS memory demand to such an extent that if

MOS memory were excluded from the numbers in the second quarter, demand growth would be less than 1.0 percent.

Worldwide Semiconductor Demand Forecast by Product—1989 and 1990

Table 5-5 presents the worldwide demand estimate and forecast by semiconductor product. The total demand CAGR for 1988 through 1990 is 7.3 percent. The highest-growth products are MOS memories, with a 25.7 percent CAGR, and optoelectronic devices, with 9.5 percent CAGR. Bipolar memory is forecast to decline steadily through the period as BiCMOS memory replaces it.

Worldwide Semiconductor Demand Forecast by Region—1989 and 1990

Table 5-6 presents the 1989 and 1990 forecast and 1988 estimated numbers by region. Not surprisingly, the Asian ROW region is forecast to enjoy the highest growth, with a CAGR of 15.9 percent; Europe should enjoy the next highest, with a 6.5 percent CAGR. The North American region is forecast to have a CAGR of 6.7 percent, barely ahead of Japan's estimated 4.1 percent.

North American Demand Forecast—1989 and 1990

Figure 5-9 shows the forecast North American semiconductor demand by quarter. The first half of 1989 is expected to experience relatively strong positive growth, with 4.7 percent and 5.3 percent increases in demand for the first and second quarters, respectively. Demand growth will decline to 0.7 percent in the third quarter, followed by negative 0.9 percent growth in the fourth quarter. Nevertheless, the strong first half is expected to yield more than 15.0 percent growth for the year.

Table 5-5

Worldwide Semiconductor Consumption by Product—1988-1990
(Millions of Dollars)

	1988	1989	1990	Growth 1989/1990	CAGR 1988-1990
Total Semiconductor	$50,859	$57,138	$58,516	2.4%	7.3%
Total IC	$41,068	$47,470	$48,941	3.1%	9.2%
Bipolar Digital	$ 5,200	$ 4,532	$ 4,232	(6.6%)	(9.8%)
Memory	689	528	479	(9.3%)	(16.6%)
Logic	4,511	4,004	3,753	(6.3%)	(8.8%)
MOS Digital	$26,988	$33,942	$35,371	4.2%	14.5%
Memory	11,692	17,526	18,473	5.4%	25.7%
Micro	7,144	7,244	7,632	5.4%	3.4%
Logic	8,152	9,127	9,266	1.5%	6.6%
Linear	$ 8,880	$ 8,996	$ 9,338	3.8%	2.5%
Total Discrete	$ 7,612	$ 7,566	$ 7,469	(1.3%)	(0.9%)
Total Optoelectronic	$ 2,179	$ 2,101	$ 2,106	0.2%	9.5%

Note: Excludes captive consumption

Source: Dataquest
September 1989

Table 5-6

Regional Semiconductor Consumption—1988-1990
(Millions of Dollars)

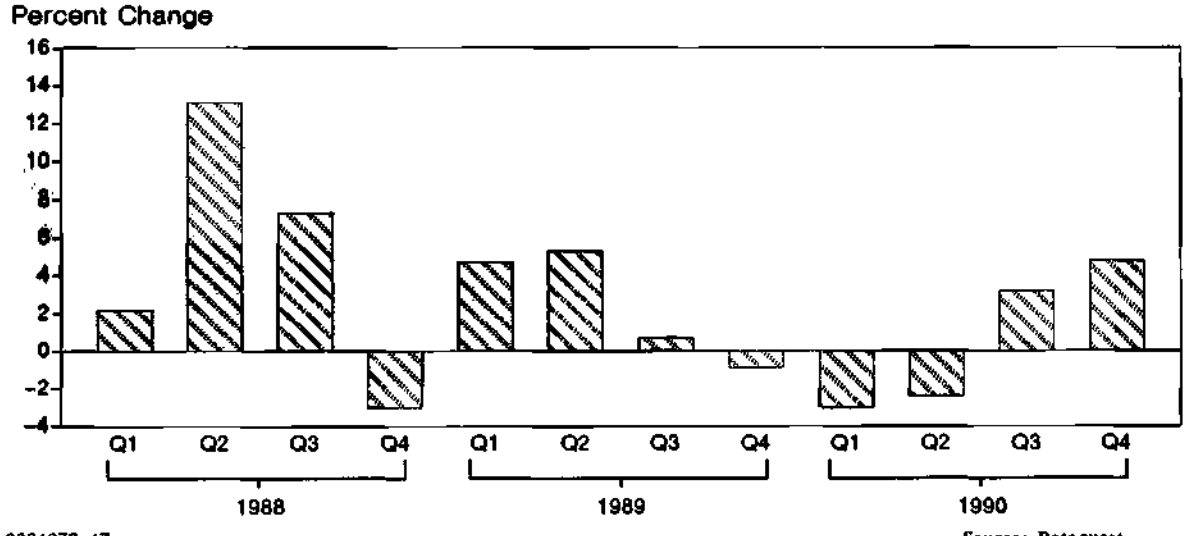
Region	1988	1989	1990	Percent Share 1988	Percent Share 1990	Growth 1989/1990	CAGR 1988-1990
North America	$15,844	$18,221	$18,025	31.2%	30.8%	(1.1%)	6.7%
Japan	20,772	22,446	22,492	40.8	38.4	0.2%	4.1%
Europe	8,491	9,738	10,368	16.7	17.7	6.5%	10.5%
Asian ROW	5,752	6,733	7,631	11.3	13.0	13.3%	15.2%
Total	$50,859	$57,138	$58,516	100.0%	100.0%	2.4%	7.3%
Annual Growth	31.9%	12.3%	2.4%				

Note: Excludes captive consumption

Source: Dataquest
September 1989

Figure 5-9

Quarterly U.S. Semiconductor Demand Forecast—1989-1990



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Source: Dataquest
September 1989

Negative growth in the fourth quarter of 1989 will carry over into the first half of 1990 before a recovery begins in the third quarter. Total 1990 demand is expected to decline 1.1 percent from the 1989 level.

Table 5-7 presents the North American forecast by semiconductor product for 1989 and 1990, along with the estimated 1988 numbers. The dominant influence is, of course, MOS memory, with a forecast annual growth of approximately 55.0 percent in 1989. However, MOS memory will experience negative growth of 2.6 percent in 1990. Microdevices will decline 6.4 percent throughout 1989 and realize more than 3.0 percent growth in

Table 5-7

North American Semiconductor Consumption—1988-1990
(Millions of Dollars)

	1988	1989	1990	Growth 1989/1990	CAGR 1988-1990
Total Semiconductor	$15,844	$18,221	$18,025	(1.1%)	6.7%
Total IC	$13,815	$16,155	$15,994	(1.0%)	7.6%
Bipolar Digital	$ 2,012	$ 1,772	$ 1,613	(9.0%)	(10.5%)
Memory	235	218	192	(11.9%)	(9.6%)
Logic	1,777	1,554	1,421	(8.6%)	(10.6%)
MOS Digital	$ 9,606	$12,152	$11,997	(1.3%)	11.8%
Memory	4,298	6,673	6,502	(2.6%)	23.0%
Micro	2,707	2,535	2,617	3.2%	(1.7%)
Logic	2,601	2,944	2,878	(2.2%)	5.2%
Linear	$ 2,197	$ 2,231	$ 2,384	6.9%	4.2%
Total Discrete	$ 1,676	$ 1,710	$ 1,663	(2.7%)	(0.4%)
Total Optoelectronic	$ 353	$ 356	$ 368	3.4%	2.1%

Note: Excludes captive consumption

Source: Dataquest
September 1989

1990. Demand for logic will increase 13.2 percent in 1989, but will decline 2.2 percent in 1990. The growth by product is so influenced by MOS memory that, if it were removed from the mix, North American demand growth over the two-year period essentially would be zero.

Four Strategic Issues

What Are the Semiconductor Demand Drivers?

The driving force behind the 1989 and 1990 demand forecast shown in Table 5-5 is MOS memory, particularly DRAMs and SRAMs. DRAM prices are expected to stay firm through the second quarter of 1989, after which a steady decline is expected. Thus DRAM demand growth in dollar terms is forecast at 46.6 percent for 1989 and at negative 8.1 percent for 1990. Unit growth is forecast at 10.0 percent for 1989.

This forecast is very dependent on DRAM pricing assumptions because, as mentioned earlier, DRAMs make up such a large portion of the product mix. This dependency and the underlying pricing assumptions are discussed in the following paragraphs.

Products within the data processing segment—PCs, technical workstations, graphics workstations, and medium-scale business computers—are driving much of the DRAM/SRAM demand. New applications for MOS memories are emerging that include digital copiers, digital fax machines, digital VCRs, and extended-definition TV (EDTV).

The outlook for microdevices and MOS logic is significantly different. Since the PC industry is expected to have slower growth during 1989 than in 1988, microprocessor growth should be correspondingly slower, at 1.4 percent in 1989 and 5.4 percent in 1990. MOS logic growth is forecast at 12.5 percent in 1989 and 1.0 percent in 1990.

Optoelectronic and discrete devices, primarily used in communications and consumer electronic products, are forecast to have lackluster growth. Optoelectronic growth is expected to have a negative 3.5 percent growth in 1989 and less than 1.0 percent growth in 1990. Discrete devices are projected at a negative 0.6 percent growth in 1989 and a negative 1.3 percent growth in 1990.

What Caused the Regional Shift in Worldwide Semiconductor Demand from 1984 through 1988?

The regional demand for semiconductors has changed dramatically over the last four years, as mentioned earlier in this chapter in the subsection entitled "Semiconductor Demand by Region—1984-1988." A recap is as follows:

- In 1984, Japan and the Asian ROW countries represented $11 billion, or only 38 percent of the $29 billion total, whereas North American demand in 1984 was $13 billion for a 45 percent share.
- The 1984 North American demand for electronic equipment constituted 44 percent of the worldwide equipment demand, while the Japanese and Asian ROW regions' share was only 21 percent. By 1988, the North American equipment demand fell to 40 percent, and the Japanese and Asian ROW share climbed to 27 percent.
- The North American share of electronic production fell much further, as indicated by the decline in semiconductor demand share from 45 percent to 31 percent.

There are three primary causes for this dramatic shift. First, North American equipment producers moved offshore. By 1984, most of the consumer electronics producers had moved their production to Asian sites where the low cost of labor was more favorable to high productivity and competitiveness. Many data processing, communications, and industrial equipment suppliers either had done the same or were having subassemblies manufactured offshore for final assembly and test in North America. This ongoing shift of U.S. equipment production to more favorable economic climates is one obvious cause of the observed shift in semiconductor demand (see Chapters 2 and 4 for further information).

Second, a shakeout occurred among U.S. suppliers. Close examination of Table 5-4 shows that in 1985, a 15.6 percent decline took place in worldwide semiconductor demand, and a precipitous 28.0 percent decline occurred in U.S. demand. Much of the observed shift in regional semiconductor demand occurred in this 1985 and 1986 recession period, which suggests an additional cause for the observed shift.

To find the additional cause requires digging deeper into the events surrounding 1984 through 1986. Chapter 4 identified 1984 as a boom year, particularly for relatively new producers of PCs and related equipment and communications equipment producers. Excessive demand accounted for the apparent success of many of these producers. But when the demand fell off in 1985, their fundamental lack of competitiveness could not withstand the onslaught of Japanese and Asian ROW competitors in a declining market. As a result, many of these new U.S. equipment producers fell by the wayside rather suddenly during 1985 and 1986.

Any slack in the supply from this shakeout of new U.S. equipment producers was filled quickly by their Asian ROW and Japanese counterparts. The former U.S. demand for semiconductors suddenly shifted to Asia and Japan as the "victor's" equipment sales filled the void.

The third primary cause for this dramatic shift in demand share to Japan has been the change in the exchange rate caused by the devaluation of the dollar beginning in 1986. Indexed against the 1984 exchange rate of 237 yen/dollar, the volume in yen of the worldwide semiconductor demand increased only 33 percent from its 1985 level. The Japanese share has increased far less than otherwise observed in terms of current dollars.

As a result of these circumstances, the Asian ROW region experienced the highest demand CAGR from 1986 to 1988—41.7 percent—followed by Japan with 35.6 percent. Europe recorded the third highest CAGR—21.0 percent—and the United States maintained a still healthy 19.4 percent CAGR. In U.S. dollars, the 1988 value of both the Japanese and Asian ROW regional demand nearly tripled from 1985.

Thus, the extraordinary sustained growth in semiconductor demand from 1985 to 1988 was by and large enjoyed in Japan and the Asian ROW countries, although all regions experienced healthy growth during the period.

What Is the Impact of Regional Economic Conditions on Semiconductor Demand for 1989 and 1990?

The following paragraphs summarize Chapter 3's detailed forecasts of each region's economic climate and Chapter 4's analysis of the impacts of these forecasts on each region's electronic equipment demand and production, and relates them to the regional forecast of semiconductor demand given in Table 5-6. For more detailed information, please refer to the appropriate chapter.

North America

The U.S. economy grew 4.0 percent in terms of real GNP in 1988. The real capital spending growth in 1988 was nearly 10.0 percent over 1987, but is forecast to decline to slightly less than 5.0 percent for both 1989 and 1990. North American electronic equipment production grew more than 8.5 percent in 1988. But because of the slowing of capital spending and reduced competitiveness in export markets, electronic equipment production growth in the United States is projected at 7.0 percent in both 1989 and 1990.

This estimate assumes that the exchange rate-derived competitiveness of U.S. equipment producers continues to enable them to at least hold their existing market share of export markets in Europe. As the U.S. dollar rises, U.S. electronic exports become less competitive in foreign markets. As 1989 unfolds, U.S. interest rates, labor costs, and inflationary pressures suggest that U.S. fundamental competitiveness will be challenged during the expected period of reduced worldwide market for electronic equipment.

If the U.S. dollar rises very much above 140 yen/dollar and 2 deutsche marks/dollar in 1989, the impact of this effective price increase in Europe and Asia, coupled with higher domestic costs, could invalidate the forecast level of export and thus reduce the actual equipment production to be less than what was forecast.

From Dataquest's estimates of the North American growth of electronic equipment production by application segment, the data processing and communications segments should realize the highest growth over the forecast period, led by PCs and related peripherals, high-performance graphics workstations, and LANs. Growth of the data processing equipment segment is forecast at 11.3 percent for 1989; growth of communications is projected at 7.5 percent.

As expected from the previous paragraphs, the North American semiconductor demand's highest segments are data processing, communications, and industrial. However, by far the most influential end product in the North American semiconductor demand forecast is the personal computer.

That the production of PCs is critical to the health of U.S. semiconductor demand is easily appreciated when one considers that PCs alone account for more than 11.0 percent of North American semiconductor consumption. Dataquest's North American semiconductor demand forecast is based on the forecast that the unit quantity of PCs produced in the United States will decline to 9.8 percent growth from 1988's 13.0 percent annual growth rate. Dataquest expects growth of PC unit shipments to further slow to less than 9.0 percent in 1990.

Japan

The Japanese economy is very strong, with a 1988 annual growth of 5.8 percent. This growth is expected to decline slightly over the forecast period to 4.5 percent in 1989 and 3.8 percent in 1990. This estimate assumes some decrease in Japanese exports and a continued healthy growth in imports. The Japanese domestic electronic production growth rate therefore is expected to decline from traditional double-digit rates to a more modest 5.0 percent in 1989 and 1.0 percent in 1990.

The Japanese marketing strategy is to focus its sales of consumer products on its still-buoyant domestic demand, while aiming sales of computers, communications, and industrial equipment to export markets.

The requisite export level to sustain the forecast GNP growth assumes that the Japanese economy will continue to sustain historic productivity levels. Japanese competitiveness as an exporter and even as a domestic supplier will be challenged because of the strong yen and increasing costs within Japan. However, many Japanese producers have moved portions of their equipment production offshore to Thailand, Malaysia, and Singapore to reduce costs and assure competitiveness both domestically and worldwide.

Despite challenges to Japanese competitiveness, the primary growth segments of equipment production

will be data processing, which is forecast to grow more than 35 percent in dollar terms in 1989 before decreasing to less than 10 percent growth in 1990. New applications such as EDTV, point-of-sale (POS) terminals (required by Japanese retailers to handle the new sales tax), and various high-performance consumer products are expected to provide growth by 1990.

The forecast decline in Japan's electronic production growth rates is the result of the following:

- The shifting of a portion of Japan's equipment production to the Asian ROW and European regions
- The reduction of export levels due to the strong yen and the need to balance Japan's trade surplus
- The slowing of demand from the United States and Europe as a result of the forecast global economic "soft landing" in 1990

Japanese semiconductor demand growth will drop to just more than one-half of U.S. demand growth in 1989 (8.1 percent), before declining to a 0.2 percent growth in 1990 (see Table 5-6). The reduced 1990 growth in dollar terms is the direct result of declining DRAM prices and reduced electronic equipment growth, resulting from Japanese electronic manufacturing shifts to Asia and Europe.

Europe

The GNP/GDP of the OECD European countries enjoyed healthy 5.8 percent growth in 1988 but is forecast to decrease slightly, to 4.5 percent in 1989 and 3.8 percent by 1990. Annual capital spending growth will be sustained at nearly 7.0 percent in 1989 and decrease to 5.5 percent by 1990. Preparations for the unified 1992 European market will sustain a higher level of electronic equipment demand than would otherwise be expected under the global economic slowdown expected through the forecast period. During the next four years, the European market offers some unique opportunities and challenges. Many local and multinational companies, including those from the United States, Japan, and the Asian ROW region, are building production facilities in Europe to take advantage of Europe 1992. These facilities will purchase semiconductors locally to receive favorable tax treatment, so additional semiconductor production capacity is building up in Europe as well. Because of this 1992 effect, some additional electronic equipment production and the resultant semiconductor consumption will shift into Europe from the other regions during 1989 and 1990.

PCs were the driving force for European semiconductor demand growth in 1988, particularly in MOS microdevices, memory, and bipolar digital logic. PC production has slowed since the fourth quarter of 1988, and semiconductor demand, except for 1Mb DRAMs, has collapsed.

Therefore, Europe is forecast to increase semiconductor consumption 14.7 percent in 1989 but to sustain a positive 6.5 percent growth in 1990 and thus realize the second-highest semiconductor demand growth behind that of the Asian ROW region.

Asian ROW

The Asian ROW countries are forecast to experience a slight decline in real GNP/GDP growth from their historic double-digit growth levels to the 7.0 to 9.0 percent range during 1989 and 1990. Both consumer and capital spending are forecast at an aggregate 7.5 percent growth rate as these economies continue their course of rapid expansion through export. Because North America constitutes a large portion of their export market (40.0 percent), some slowing in exports is expected in late 1989 and early 1990, but this could be offset by increased exports to China, Thailand, and other developing countries.

As mentioned above, the Asian ROW region also is the beneficiary of much of the Japanese consumer equipment producers' move offshore to sustain competitiveness. A portion of its equipment production growth forecast reflects this shift in production from Japan.

The primary drivers of semiconductor demand in the Asian ROW region is PC and consumer product production. Recent softness in North American and European PC demand caused semiconductor demand to slow in the fourth quarter of 1988 and first quarter of 1989. Considerable consumer product production growth is forecast over the next two years, as the domestic markets of China and Thailand begin to open up.

Thus, Asian ROW semiconductor demand is forecast to descend from the high growth peak of more than 46.0 percent in 1988 to a still healthy 17.1 percent growth in 1989 and a somewhat slower 13.3 percent growth in 1990.

What Are Price and Availability for Critical Devices?

The key semiconductor devices to be under pressure for price and availability appear to be memory-related: DRAMs and SRAMs. Some concern will exist about price and availability of high-performance 32-bit microprocessors, but with the expected slowdown in the computer industry, it will not be too strong.

Figure 5-10 illustrates the sharp price decline that is anticipated for 1Mb DRAMs and 256K DRAMs over the forecast period. The current 1Mb DRAM volume contract range of $16.75/unit in the United States ($14.59/unit in Japan) is expected to plummet to less than $7.00/unit by the end of 1990. This price decline is based on the anticipated balance of declining demand with the supply of 256K devices and increasing yields of 1Mb devices to meet demand by the second quarter of 1989.

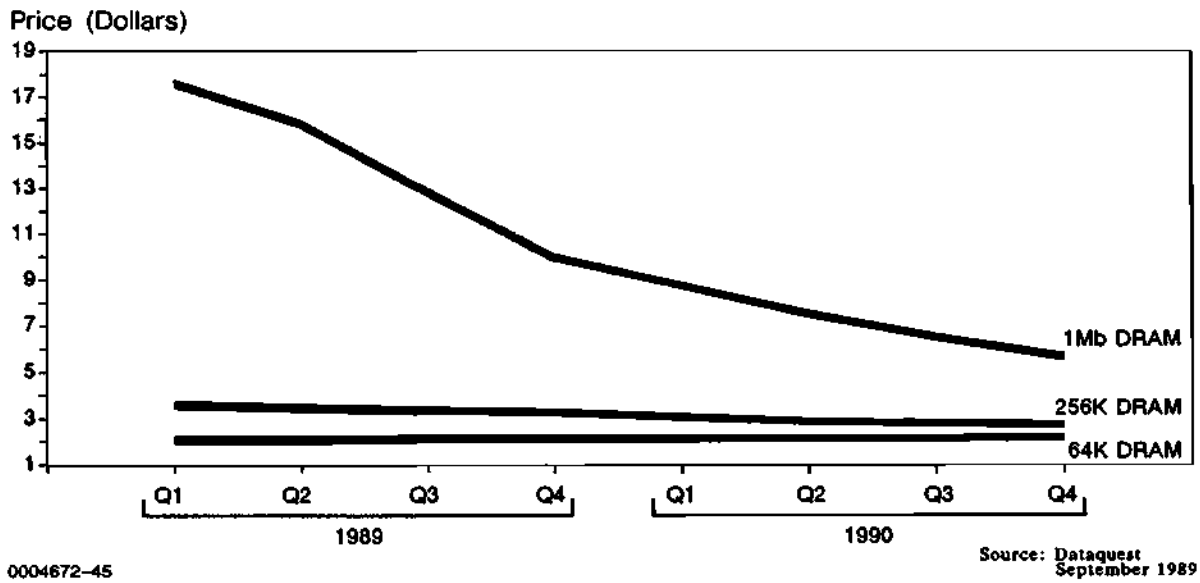
The amount of capacity allocated to manufacturing DRAMs has had a definite effect on prices of other memory devices such as slow SRAMs, video RAMs, and x4 DRAMs. Suppliers of these devices heretofore have had little incentive to switch capacity from the highly profitable DRAMs, given their inflated prices. The supply of these devices is expected to balance demand by the third quarter of 1989, which should then cause prices of these devices to decline as well.

As 1989 progresses, lower orders from equipment producers should continue to cause a decline in both unit quantity and average selling price (ASP) growth. As this occurs, the lead times and ASPs for high-performance 32-bit microprocessing units (MPUs) are expected to decline during the second quarter as well.

There are many new market forces influencing the DRAM price and availability forecast. The regional dominance that characterizes the MOS memory business may prevent the natural market forces from playing their normal significant roles in determining the trajectory of ASP declines. The extent to which this becomes a reality in 1989 will have profound implications for U.S. memory producers, semiconductor users, and potentially for the direction of U.S. trade policy.

Figure 5-10

DRAM Price Trend Forecast



CHAPTER 6

Semiconductor Production

In 1988, more than $54 billion worth of semiconductor products were manufactured worldwide. The semiconductor industry supplies billions of individual semiconductor devices to satisfy semiconductor demand generated by worldwide electronic equipment producers. These devices consist of many different types of semiconductor products including diodes, transistors, ICs, and optoelectronic devices.

More than 200 companies throughout the world produce semiconductor devices. These companies range in size, products, and marketing strategies from giant multinational corporations engaged in volume production of commodity ICs to much smaller companies addressing specialized market niches.

Despite their diversity, semiconductor companies share a common purpose: the miniaturization of electronic devices through the use of semiconductor materials. The technology behind this industry involves elements of physics, chemistry, and electronic theory that are at the cutting edge of their respective disciplines.

This chapter describes the underlying forces that influence semiconductor production. The chapter is organized into the following three sections:

- Background—The underlying forces of production are addressed as follows:
  - What are the key characteristics of semiconductor manufacturing?
    - Two-stage process
    - Cost and investment structure
    - High-cost wafer fabs
    - Offshore shift of back-end process
    - Demand for high-volume technology driver
  - Who manufacturers semiconductors?
  - Where are semiconductors manufactured?
- Production forecast—1989 and 1990 worldwide and regional production forecast by region and location of company headquarters
- Strategic issues—Key issues and opportunities relating to the semiconductor production forecast

Background

Key Characteristics of Semiconductor Manufacturing

In general, semiconductors are manufactured in two major stages:

- The front-end (wafer fabrication) process
- The back-end (device assembly and test) process

The Front-End or Wafer Fabrication Process

The front-end process is a complex sequence involving hundreds of individual process steps that transform bare silicon wafers to fully fabricated wafers made up of multiple integrated circuits. For example, a state-of-the-art 1Mb DRAM process can have as many as 200 to 300 process steps with 15 or more mask layers.

During the semiconductor manufacturing process, the bare silicon wafer is processed through a repetitive sequence of thin film deposition, photolithographic patterning, and etching steps. A series of masks containing the circuit design information are used to transfer the IC pattern into silicon. The fabrication process is carried out in an extremely clean environment to eliminate defects that would otherwise render the IC nonfunctional. The final IC consists of thousands of transistor devices that are connected together in a specified pattern to perform the desired electrical function. Each processed wafer contains multiple rows of identical IC chips that also are known as die. The wafer can now be diced into individual chips and packaged.

The Back-End or Test-and-Assembly Process

The first part of the back-end process consists of electrically testing the finished wafers to check all the chips for adherence to the circuit functional specifications. The bad chips are stained with ink and are rejected from subsequent assembly processing. Next, the wafer is diced and the good chips are separated and assembled in ceramic or plastic packages for connection to the outside board-level circuits. The finished integrated circuit package finally is tested again to check for functional performance before being shipped to the customer.

Equipment and supplies (materials) necessary for semiconductor production are categorized as fron-end and back-end equipment and materials. (For further information about semiconductor manufacturing equipment and materials, see Chapter 7.)

Cost and Investment Structure

The manufacturing cost and investment structure for the semiconductor manufacturing process can be characterized as follows:

- Massive capital investment in wafer fab (front end) capacity
- Considerable labor cost for test and assembly (back-end process)
- Materials costs associated with the procurement of the raw silicon wafers

Manufacturing costs are determined by the variable or per-unit cost in terms of materials and labor cost, and the amortization of the fixed capital investment. The biggest impact is that of the amortization. Thus, true profitability and return on investment are critically dependent on the efficiency of the process, or how many devices can be produced for a given fixed investment cost.

Another way of saying this is the profit and return on investment (ROI) of a semiconductor producer is most dependent on the yield from the manufacturing process. (Yield is the number of saleable devices expressed as a percentage of the total devices produced.) Obviously, the higher the yield, the higher the efficiency, and therefore the higher the profit and ROI.

Manufacturers continually seek to improve yields. Many techniques are used, but such improvements most often are the result of new manufacturing technology. The semiconductor equipment suppliers provide the new technology and therefore are critical contributors to the success of semiconductor producers.

High-Cost Wafer Fabs

Because of the high cost of wafer fabs, the semiconductor manufacturing industry is undergoing structural change. In the past, semiconductor producers typically performed all or most of the production steps themselves. Today, however, some newer companies are separating the device design function from the device fabrication process. Such companies add value through innovative design and customer service as opposed to improved manufacturing.

Among companies that possess manufacturing capabilities, marked differences exist in the number of support functions they integrate into the fab process. Such support functions include fabrication of the packaging in which the devices are assembled, growing and preparing the raw silicon wafers, manufacturing the masks used in the photolithographic process, and other related functions. Larger and older companies such as IBM or TI tend to be more integrated. Smaller and newer companies tend not to perform as many of these functions. Intel, for example, purchases masks, wafers, and packages.

Recently, there has been a proliferation of companies offering semiconductor manufacturing services. These include device design, mask-making, wafer fabrication (wafer foundries), assembly and packaging, and testing services. These companies make it possible to design, manufacture, and market semiconductors without the huge investment in manufacturing equipment, CAD/CAM equipment, or engineering manpower. They serve the needs of other semiconductor manufacturers and semiconductor users alike.

Another reason for the structural changes described previously is the projected increase in wafer fab productivity. Dataquest estimates that by the year 2000, the if-sold value potential of a modern wafer fab facility will be as high as $670 million. This would seem to limit such investments to only the top few billion-dollar companies and encourage "foundry-for-hire" agreements among many other companies.

Offshore Shift of Back-End Process

Japanese semiconductor producers leveraged their economy's superior productivity characteristics—low interest rates, patient capital, and low-cost, highly skilled labor—and developed a competitive edge on U.S. producers. In response, U.S. semiconductor producers transplanted labor-intensive assembly operations offshore to Asian ROW countries. Today, it is not unusual for wafers to be fabricated in one country, devices assembled in a second, and final testing and shipping to occur in a third. This mobility within the manufacturing process is made possible by the small size and low weight-per-dollar value of semiconductor devices.

This search for the lowest-cost allocation of production resources has led increasingly more companies to invest in overseas assembly plants. This trend is expected to continue, although it eventually may be slowed by increased automation of the assembly process.

Demand for High-Volume Technology Driver

Dataquest's Semiconductor Equipment and Materials Service (SEMS) estimates that because of their huge production volumes, particularly in MOS DRAMs, Japanese producers have as much as a 70 percent cost advantage over U.S. producers. This advantage has the following two primary sources:

- Japan frequently has brought new products through the development process into the market ahead of the United States. This allows Japanese manufacturers to move down the learning curve and to charge lower prices than U.S. suppliers once the latter enter the market. The only way the United States can catch up is to produce significantly higher volumes.
- Most important is that Japanese producers have a decided advantage over their competition in manufacturing yields. At the heart of the yields issue is the need for leading-edge, high-volume products that can serve as technology drivers that improve yields for all products. Since the early 1980s, MOS DRAMs have served this function for semiconductor producers. The United States lost most its the DRAM market share to the Japanese by 1986. Since then, the Japanese have exploited their massive DRAM production technology for superior yields and the resultant cost advantages in many other products.

Who Manufactures Semiconductors?

More than 200 semiconductor manufacturers exist throughout the major geographical regions. These companies can be classified as follows:

- Independent manufacturers
- Divisions of major corporations
- Captive manufacturers

The first two of these classifications compete in the worldwide merchant market to supply semiconductor products to electronic equipment producers worldwide. Captive manufacturers supply products only for internal consumption to satisfy a company's own electronic equipment production requirements. It is important to note that the merchant and captive supplier classifications are more of a U.S. notion than a Japanese one. In Japan, most semiconductor production is integrated within larger electronics companies.

As mentioned previously, the search for the lowest manufacturing cost has forced producers to become international in scope, at least in manufacturing. The high capital investment required is creating a restructuring of the type of services and products offered as well.

Independent Manufacturers. Most manufacturing (about 70 percent in the United States) is performed by independent manufacturers. Semiconductor manufacturing and sales constitute the major part of their businesses. Their survival depends on their performance in the semiconductor industry. They have no guaranteed markets or financing. In general, they are aggressive, competitive, and innovative in bringing new technologies to market. Companies in this category include Advanced Micro Devices (AMD), Intel, Motorola, National Semiconductor, and TI.

Divisions of Major Corporations. Many major corporations in the United States, Japan, and Europe have divisions that produce semiconductors. These divisions are distinct from captive producers because they actively sell their devices on the open market (merchant market). Most, but not all, of these companies market at least a small portion of their output to their parent companies. All benefit from the financial resources of the parent, which is a distinct advantage considering the huge capital requirement that characterizes semiconductor production.

In some cases, these companies also have the advantage of a small sheltered market (to the parent) for some of their products. On the other hand, they can suffer from parental management decisions that are not in their best interests or that fail to reflect an understanding of semiconductor business issues.

In Japan, these companies are referred to as integrated. The Japanese have skillfully combined the financial strength of the parent company, the integration of device design with end-product design to maximize end-product performance and competitiveness, and the cost benefits of volume-production devices for the merchant market. In Japan, both the integrated semiconductor producer and the parent equipment manufacturer win.

Worldwide examples divisions of major corporations include AT&T, Harris, Hitachi, NCR, Nippon Electric (NEC), Philips, Rockwell, Siemens, Toshiba, and Westinghouse.

Captive Manufacturers. Companies that maintain semiconductor manufacturing facilities for production of devices solely for their own use are referred to as captive manufacturers. As semiconductors become more important to major equipment manufacturing companies, these companies are realizing the value of captive facilities that allow device design to be integrated with final system design, thus maximizing the leverage of the underlying silicon.

Many of these captive facilities provide services and unique devices that are not available in the merchant market. That is, they define device requirements based on final system requirements, then design and make what they cannot buy. Captive manufacturers fulfill semiconductor demand that is not available to the other suppliers to the merchant market.

Examples of captive manufacturers are General Motors, Hewlett-Packard, IBM, and Unisys.

Top 20 Worldwide Semiconductor Manufacturers

Table 6-1 shows the overall ranking of the top 20 worldwide semiconductor producers by total 1988 revenue. Figure 6-1 shows the revenue growth from the top 10 companies from 1986 through 1988. Several items are noteworthy, including the following:

- The number one producer—NEC—has nearly doubled its revenue in dollar terms since 1986.
- Toshiba has experienced higher growth than either NEC or Hitachi, and has firmly established itself in the number two position, up from number three in 1986.
- Of all U.S. producers in the top 20, only Intel recorded a 1988 annual growth rate exceeding that of the industry (32 percent). AMD, AT&T, and National Semiconductor recorded annual growth rates of less than one-half the industry rate; all but AMD fell at least 3 positions in rank from 1987. Intel's growth can be attributed mostly to its success with its proprietary i80X86 16/32-bit microprocessor family. Because of such rapid growth, Intel moved up from position 10 in 1987 to position 7 in the 1988 ranking.
- Samsung, with 176 percent annual growth, made the top 20 for the first time in 1988, primarily due to its DRAM strategy. This is a sign that South Korea is following its own DRAM strategy as a vehicle to gain position in the industry, just as Japan did in the late 1970s.
- Philips-Signetics experienced only 10 percent growth in 1988, thus falling to tenth position behind Mitsubishi and Matsushita.

Another important industry characteristic that is shown in Table 6-1 is that of market concentration, which is illustrated in Figure 6-2. This figure shows that the top 10 companies garnered nearly 60 percent market share; the top 25 accounted for 84 percent of the market. The remaining companies (ranked 26 through 116) accounted for only 16 percent of the market.

Company Market Shares by Product Category

The products driving 1988's phenomenal growth were MOS DRAMs and SRAMs, MOS microdevices, and MOS ASICs. Tables 6-2 through 6-8 rank the top 20 producers in the following major semiconductor product classifications: total integrated circuit, total bipolar digital, total MOS digital, MOS memory, analog ICs, discrete, and optoelectronic.

The Japanese Example: The Advantage of Integrated Producers over Independent Producers

Japan's mostly integrated semiconductor producers' rapid rise to dominance over the United States' mostly independent semiconductor producers provides empirical evidence that the Japanese model works best. The Japanese model, however, was very much influenced by the IBM company model, and the IBM model included integrated semiconductor production.

As mentioned in Chapter 5, Japan's national objective was to develop its electronic equipment production to a world-class level. Data processing, consumer, and communications were the chosen market segments. As a strategy, Japan licensed product technologies and manufacturing rights, then leveraged its superior economic competitiveness and manufacturing acumen to gain foreign market share through aggressive pricing.

In 1975, the goal of this strategy became dominance over U.S. semiconductor producers. This entailed the cooperative efforts of the MITI, sources of patient capital, and a variety of large electronic equipment producers that were chosen to participate in the development of the Japanese semiconductor industry as integrated producers.

The semiconductor strategy of the Japanese integrated producers was not dissimilar to their equipment strategy and is outlined as follows:

- Capitalize on the innovations of the independent U.S. producers by obtaining licenses to the technology and/or manufacturing rights as a second source
- Focus on MOS DRAMs as the necessary technology driver
- Advance the technology through simplification, thereby reducing manufacturing costs and increasing quality and reliability. In so doing, leapfrog U.S. independent producers and bring 64K DRAMs to the market ahead of them
- Exploit the advantages provided by Japan's more competitive economic climate and its sheltered environment provided by MITI's protection of the Japanese market, the huge financial resources of the parent companies, and the patience of investment capital, by increasing foreign market share through aggressive pricing

This was devastating to U.S. independent DRAM suppliers. In 1975, 15 U.S. manufacturers supplied nearly all of the worldwide market; by 1986, all but 2 had been shaken out of the market. The remaining 2 retained less than a 25 percent share of the entire memory market by 1987. This happened because the Japanese producers won large shares of the 16K DRAM market through aggressive pricing and superior quality from 1978 through 1980 and were first to market with 64K devices in 1980. In 1982, they announced sampling of the 256K MOS DRAM, and subsequently all but the aforementioned 2 U.S. producers withdrew from DRAM production from 1982 through 1985.

Can U.S. Standalone Semiconductor Producers Survive?

We have presented empirical proof that integrated semiconductor producers have inherent advantages over independent producers. Independents, of course, can argue that only in their environment can the innovations and new products that advance the industry be created and developed, and they may be right. However, at this point, the question is becoming academic and is being replaced with another much more important one: Does the standalone semiconductor producer concept of the United States—a product of the entrepreneurial spirit that is the backbone of the free enterprise system—have long-term viability in view of the superior financial resources, government support, and current market shares of the Japanese integrated producers?

The challenge for the United States is how to quickly devise ways to match the superior resources of the Japanese integrated producers while operating within the boundaries of the free enterprise system.

Table 6-1

Top 10 Worldwide Semiconductor Manufacturers for 1988

1988 Rank	1987 Rank	Company	1987 Revenue	1988 Revenue	Percent Change
1	1	NEC	3,368	4,543	34.9%
2	2	Toshiba	3,029	4,395	45.1%
3	3	Hitachi	2,618	3,506	33.9%
4	4	Motorola	2,434	3,035	24.7%
5	5	Texas Instruments	2,127	2,741	28.9%
6	6	Fujitsu	1,801	2,607	44.8%
7	10	Intel	1,491	2,350	57.6%
8	9	Mitsubishi	1,492	2,312	55.0%
9	11	Matsushita	1,457	1,883	29.2%
10	7	Philips-Signetics	1,602	1,738	8.5%
		U.S. Companies	14,930	18,586	24.5%
		ROW Companies	671	1,414	110.7%
		Japan Companies	18,450	25,942	40.6%
		Europe Companies	4,200	4,917	17.1%
		Total World Companies	38,251	50,859	33.0%

Source: Dataquest September 1989

In the MOS digital category (see Table 6-4), the remarkable growth experienced by Samsung, Sharp, and Micron Technology was because of the high demand for DRAMs. In MOS memory, changes in rank occurred among the top 10 companies (see Table 6-5). Toshiba replaced NEC in the number 1 spot, Samsung advanced 2 places, and Siemens advanced 7 places, but AMD fell to number 14 because of its lack of DRAM participation.

Where Are Semiconductors Produced?

The United States was the semiconductor innovator, and in the early years of industry development, it concentrated on building a dominant industry infrastructure within the country. In 1974, the United States controlled an estimated 62 percent of the total world semiconductor market and more than 75 percent of the worldwide IC segment. Including the market represented by U.S. captive producers, the total semiconductor market figure would be more than 80 percent.

Through the highly focused efforts of the Japanese integrated producers, initially on DRAMs and subsequently on most other products, the situation looked substantially different by 1988. Figure 6-3 shows that in 1988, the Japanese-based companies accounted for more than 50 percent of the total semiconductor market; the share of U.S.-based companies had fallen to 37 percent of the merchant market.

European-based companies' share of the world market also declined, from 17 percent in 1974 to 10 percent in 1988, while the share of companies based in Asian ROW countries captured almost a 3 percent market share in 1988, up from zero in 1980.

Table 6-9 compares the market share of companies based in the United States by major product category in 1980 and 1987. Table 6-10 shows the impact of 1988 on these figures and reflects the increasing presence of the Asian ROW companies in the MOS digital category as the U.S. producers' share continued to decline.

Table 6-11 shows the regional semiconductor demand as developed in Chapter 5 and the share of each region's demand supplied by regional company base for 1986 through 1988. As Table 6-11 shows, the U.S. companies' share of the total U.S. demand declined from 78.4 percent in 1985 to 70.5 percent in 1988. The Japanese companies' share of U.S. consumption increased from 13.6 percent to 20.2 percent in the same period, along with the Asian ROW countries increase to 2.6 percent.

However, U.S. companies' share of the Japanese market increased only slightly, from 8.5 percent in 1985 to 9.5 percent in 1988, while the Japanese companies' share of the Japanese market remained a dominant 90.0 percent. Japanese and Asian ROW countries increased their penetration of the European market considerably, from 11.7 percent in 1985 to 18.8 percent in 1988.

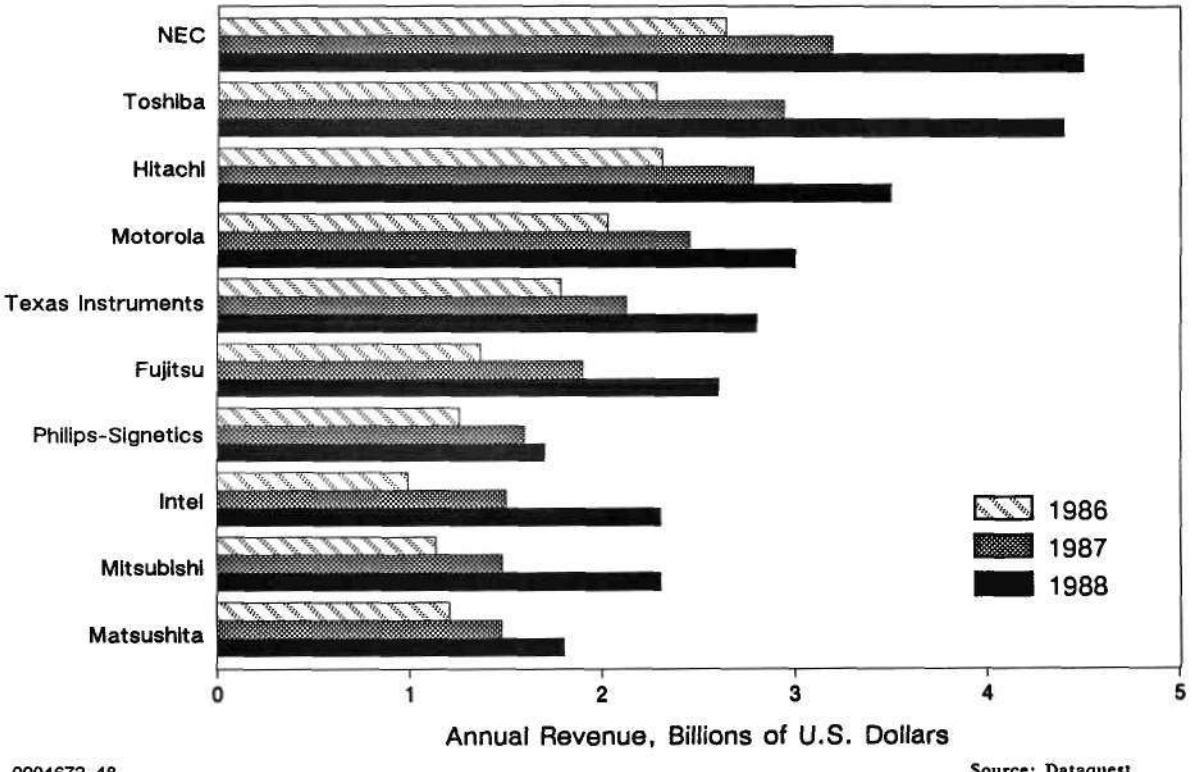
One encouraging note is that U.S. companies increased their share of the rapidly growing Asian market from 27.7 percent in 1985 to 31.6 percent in 1988. It is interesting to note that of this same rapidly expanding Asian demand, Asian producers' share was only 31.6 percent in 1988, whereas Japanese companies enjoyed a 44.1 percent share.

Why the Shift to the Pacific Rim?

Of the numerous reasons for the increased market share of Japanese and Asian producers over the past 10 years, the primary one is Japan's focused strategy embodied in its aggressive penetration of the DRAM market, as mentioned previously. Second is the U.S. companies' transfer of large portions of their manufacturing operations to foreign plants. The accompanying technology transfers have then enabled foreign producers to advance these technologies rapidly, thereby diminishing U.S. technical superiority.

Figure 6-1

Worldwide Semiconductor Market Share
Top 10 Companies—1986-1988
(Billions of Dollars)



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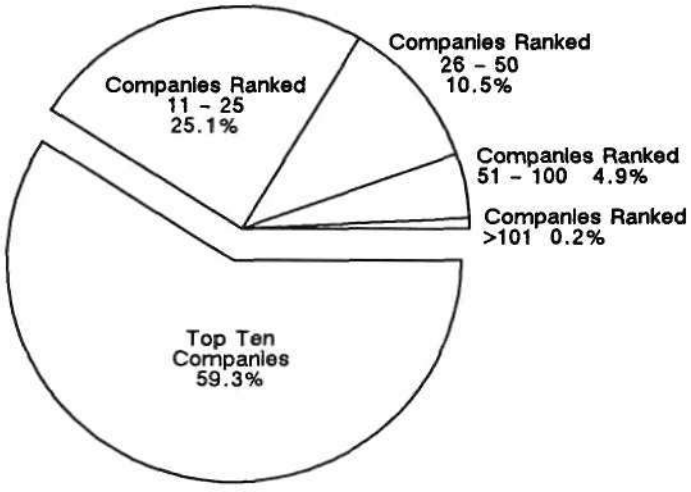
Source: Dataquest
September 1989

Figure 6-2

1988 Worldwide Semiconductor Market Share
Concentration of Revenue



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Source: Dataquest
September 1989

Table 6-2

1988 World Semiconductor Market Share Ranking
Total Integrated Circuit
(Millions of Dollars)

1988 Rank	1987 Rank	Company	1987 Revenue	1988 Revenue	Percent Change
1	1	NEC	2,795	3,884	39.0%
2	2	Toshiba	2,194	3,316	51.1%
3	4	Hitachi	1,946	2,729	40.2%
4	3	Texas Instruments	2,024	2,637	30.3%
5	6	Fujitsu	1,660	2,420	45.8%
6	7	Intel	1,491	2,350	57.6%
7	5	Motorola	1,758	2,259	28.5%
8	9	Mitsubishi	1,239	1,975	59.4%
9	8	National Semiconductor	1,431	1,575	10.1%
10	11	Matsushita	994	1,328	33.6%
		U.S. Companies	12,496	15,990	28.0%
		ROW Companies	565	1,274	125.5%
		Japan Companies	13,981	20,375	45.7%
		Europe Companies	2,845	3,429	20.5%
		Total World Companies	29,887	41,068	37.4%

Source: Dataquest
September 1989

Table 6-3

1988 World Semiconductor Market Share Ranking
Total Bipolar Digital
(Millions of Dollars)

1988 Rank	1987 Rank	Company	1987 Revenue	1988 Revenue	Percent Change
1	1	Texas Instruments	854	940	10.1%
2	4	Fujitsu	495	653	31.9%
3	2	National Semiconductor	521	550	5.6%
4	3	Advanced Micro Devices	500	536	7.2%
5	5	Hitachi	463	501	8.2%
6	6	Motorola	429	435	1.4%
7	7	Philips	405	413	2.0%
8	8	NEC	247	292	18.2%
9	10	Mitsubishi	122	127	4.1%
10	9	Toshiba	125	108	(13.6%)
		U.S. Companies	2,589	2,761	6.6%
		ROW Companies	37	50	35.1%
		Japan Companies	1,540	1,791	16.3%
		Europe Companies	594	598	0.7%
		Total World Companies	4,760	5,200	9.2%

Source: Dataquest
September 1989

Table 6-4

1988 World Semiconductor Market Share Ranking
Total MOS Digital
(Millions of Dollars)

1988 Rank	1987 Rank	Company	1987 Revenue	1988 Revenue	Percent Change
1	1	NEC	2,006	3,123	55.7%
2	2	Toshiba	1,593	2,639	65.7%
3	3	Intel	1,473	2,328	58.0%
4	4	Hitachi	1,173	1,885	60.7%
5	5	Fujitsu	1,014	1,616	59.4%
6	7	Mitsubishi	812	1,453	78.9%
7	6	Motorola	990	1,399	41.3%
8	8	Texas Instruments	784	1,271	62.1%
9	9	Matsushita	592	875	47.8%
10	10	Oki	566	841	48.6%
		U.S. Companies	6,880	9,754	41.8%
		ROW Companies	422	1,056	150.2%
		Japan Companies	8,921	14,494	62.5%
		Europe Companies	1,250	1,684	34.7%
		Total World Companies	17,473	26,988	54.5%

Source: Dataquest
September 1989

Table 6-5

1988 World Semiconductor Market Share Ranking
MOS Memory
(Millions of Dollars)

1988 Rank	1987 Rank	Company	1987 Revenue	1988 Revenue	Percent Change
1	2	Toshiba	679	1,516	123.3%
2	1	NEC	838	1,490	77.8%
3	4	Hitachi	576	1,114	93.4%
4	3	Fujitsu	634	1,067	68.3%
5	5	Mitsubishi	492	966	96.3%
6	6	Texas Instruments	445	834	87.4%
7	9	Samsung	170	650	282.4%
8	7	Intel	326	392	20.2%
9	8	Oki	193	353	82.9%
10	11	Sharp	130	344	164.6%
		U.S. Companies	1,701	2,836	66.7%
		ROW Companies	211	795	276.8%
		Japan Companies	3,909	7,597	94.3%
		Europe Companies	235	464	97.4%
		Total World Companies	6,056	11,692	93.1%

Source: Dataquest
September 1989

Table 6-6

1988 World Semiconductor Market Share Ranking
Total Analog Integrated Circuits
(Millions of Dollars)

1988 Rank	1987 Rank	Company	1987 Revenue	1988 Revenue	Percent Change
1	3	Toshiba	476	569	19.5%
2	2	National Semiconductor	495	540	9.1%
3	6	Sanyo	377	471	24.9%
4	1	NEC	542	469	(13.5%)
5	4	Philips	439	466	6.2%
6	5	Texas Instruments	386	426	10.4%
7	8	Motorola	339	425	25.4%
8	7	Matsushita	376	423	12.5%
9	10	Mitsubishi	305	395	29.5%
10	14	Sony	217	386	77.9%
		U.S. Companies	3,027	3,475	14.8%
		ROW Companies	106	168	58.5%
		Japan Companies	3,520	4,090	16.2%
		Europe Companies	1,001	1,147	14.6%
		Total World Companies	7,654	8,880	16.0%

Source: Dataquest
September 1989

Table 6-7

1988 World Semiconductor Market Share Ranking
Discrete
(Millions of Dollars)

1988 Rank	1987 Rank	Company	1987 Revenue	1988 Revenue	Percent Change
1	1	Toshiba	703	864	22.9%
2	2	Motorola	652	752	15.3%
3	3	Hitachi	625	707	13.1%
4	4	NEC	518	571	10.2%
5	5	Philips-Signetics	390	432	10.8%
6	6	Matsushita	318	377	18.6%
7	7	Mitsubishi	227	310	36.6%
8	13	Rohm	200	287	43.5%
9	11	Fuji Electric	206	279	35.4%
10	9	SGS-Thomson	213	254	19.2%
		U.S. Companies	2,051	2,171	5.9%
		ROW Companies	103	135	31.1%
		Japan Companies	3,376	4,056	20.1%
		Europe Companies	1,125	1,250	11.1%
		Total World Companies	6,655	7,612	14.4%

Source: Dataquest
September 1989

Table 6-8

1988 World Semiconductor Market Share Ranking
Optoelectronic
(Millions of Dollars)

1988 Rank	1987 Rank	Company	1987 Revenue	1988 Revenue	Percent Change
1	1	Sharp	223	285	27.8%
2	4	Sony	138	217	57.2%
3	5	Toshiba	132	215	62.9%
4	2	Hewlett-Packard	186	213	14.5%
5	3	Matsushita	145	178	22.8%
6	10	Rohm	70	109	55.7%
7	9	Fujitsu	71	105	47.9%
8	7	Siemens	85	100	17.6%
9	11	NEC	55	88	60.0%
10	8	Telefunken Electronic	77	74	(3.9%)
		U.S. Companies	383	425	11.0%
		ROW Companies	3	5	66.7%
		Japan Companies	1,093	1,511	38.2%
		Europe Companies	230	238	3.5%
		Total World Companies	1,709	2,179	27.5%

N/A = Not Applicable

Source: Dataquest
September 1989

Figure 6-3

Worldwide Semiconductor Market Shares by Company Base

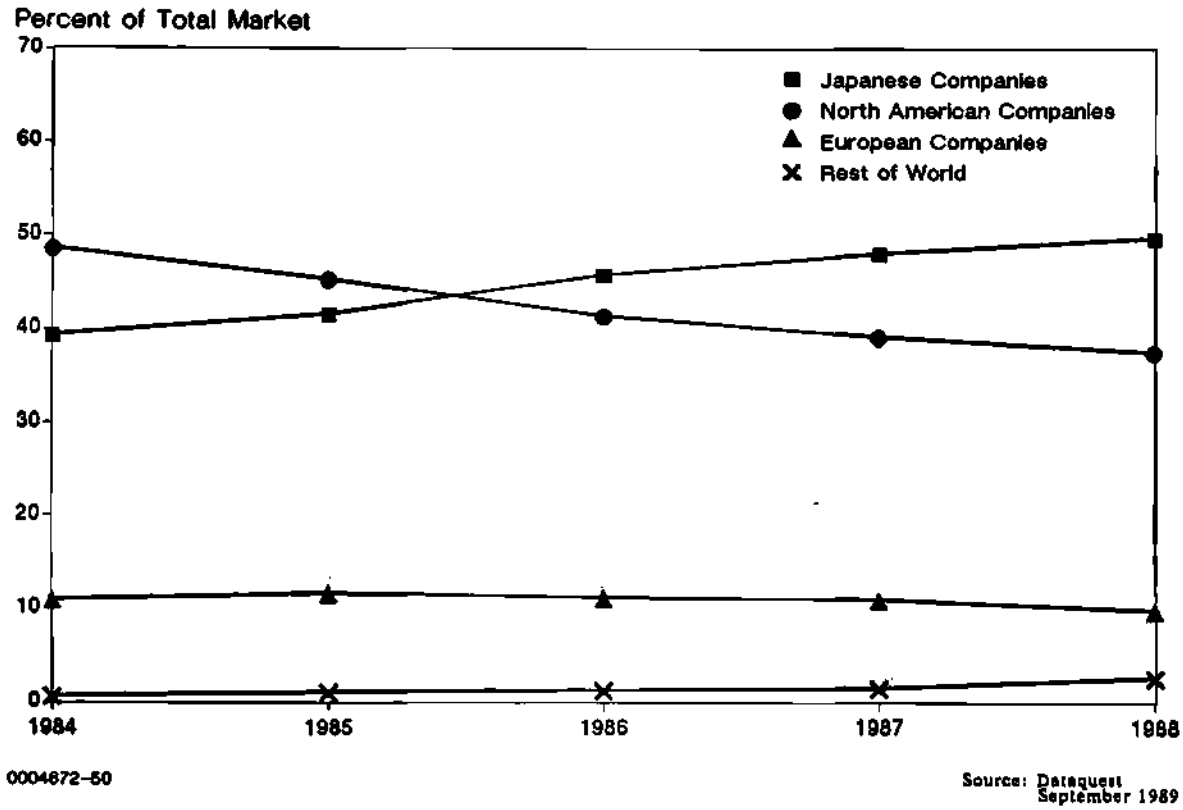


Table 6-9

U.S. Producers' Market Share—1980 and 1987

	1980	1987	Percent Change
Total Integrated Circuits	62.7%	42.0%	(20.7%)
Total Bipolar Digital	75.5%	55.0%	(20.5%)
MOS Memory	73.7%	28.0%	(45.7%)
Total MOS Digital	62.3%	41.0%	(21.3%)
Total Linear	46.5%	39.0%	(7.5%)
Total Discrete	43.5%	31.0%	(12.5%)
Total Semiconductors	57.2%	39.0%	(18.2%)

Source: Dataquest
September 1989

Table 6-10

U.S. Producers' Market Share—1987 and 1988

	1987	1988	Percent Change
Total Integrated Circuits	42.0%	40.0%	(2.0%)
Total Bipolar Digital	55.0%	54.0%	(1.0%)
MOS Memory	28.0%	25.0%	(3.0%)
Total MOS Digital	41.0%	37.0%	(4.0%)
Total Linear	39.0%	40.0%	1.0%
Total Discrete	31.0%	29.0%	(2.0%)
Total Semiconductors	39.0%	40.0%	1.0%

Source: Dataquest
September 1989

Table 6-11

Worldwide Semiconductor Consumption by Region and Regional Company Share of Production—1984-1988
(Millions of Dollars)

	1987	1988	Market Share 1987	Market Share 1988	Growth Rate 1987-1988
Regional Consumption					
North America					
U.S. Companies	$ 9,671	$11,146	75.2%	70.3%	15.3%
Japanese Companies	2,110	3,277	16.4	20.7	55.3%
European Companies	913	1,006	7.1	6.3	10.2%
ROW Companies	164	415	1.3	2.6	153.0%
Total North American Market	$12,858	$15,844	100.0%	100.0%	23.2%
Japan					
U.S. Companies	$ 1,249	$ 1,965	8.4%	9.4%	57.3%
Japanese Companies	13,588	18,640	91.0	89.7	37.1%
European Companies	70	115	0.5	0.6	64.3%
ROW Companies	20	62	01	0.3	210.0%
Total Japanese Market	$14,927	$20,772	100.0%	100.0%	39.2%
Europe					
U.S. Companies	$ 2,845	$ 3,664	43.7%	43.2%	28.8%
Japanese Companies	900	1,466	13.8	17.3	62.9%
European Companies	2,714	3,196	41.8	37.6	17.8%
ROW Companies	39	165	0.7	1.9	323.0%
Total European Market	$ 6,498	$ 8,491	100.0%	100.0%	30.7%

(Continued)

Table 6-11 (Continued)

Worldwide Semiconductor Consumption by Region and Regional Company Share of Production—1984-1988
(Millions of Dollars)

	1987	1988	Market Share 1987	Market Share 1988	Growth Rate 1987-1988
Asian ROW					
U.S. Companies	$ 1,165	$ 1,811	29.4%	31.5%	55.5%
Japanese Companies	1,852	2,569	46.7	44.7	38.7%
European Companies	503	600	12.6	10.4	19.3%
ROW Companies	448	772	11.3	13.4	72.3%
Total Asian ROW Market	$ 3,968	$ 5,752	100.0%	100.0%	44.9%
Worldwide Production					
U.S. Companies	$14,930	$18,586	39.0%	36.5%	24.5%
Japanese Companies	18,450	25,942	48.2	51.0	40.6%
European Companies	4,200	4,917	11.0	9.7	17.1%
ROW Companies	671	1,414	1.8	2.8	110.7%
Total Worldwide Market	$38,251	$50,859	100.0%	100.0%	32.9%
Annual Growth Rate	24.1%	31.9%			

Notes: Some columns may not add to totals shown because of rounding.
Merchant sales only

Source: Dataquest
September 1989

With the maturation of the industry as reflected by high-volume commodity products, the United States has not had a sufficiently productive economic environment to manufacture commodity semiconductors competitively. Many difficulties also are associated with satisfying the short-term perspective of the U.S. investment community. The constant need to provide a quick return makes it hard for independent U.S. producers to match the manufacturing resources and expertise of Japanese producers that have integrated relationships with large, diversified, and multinational parent companies that allow more favorable economies of scale, lower profit margins, and ready access to more patient capital.

Another basic problem for U.S. chip producers is the rapidly declining U.S. demand for semiconductors (see Chapter 5). This decline, combined with the considerable increase in demand from the Pacific Rim and Japan, is forcing U.S. producers to depend less on domestic consumption of their products and turn toward more effective penetration of these regions.

To the extent that historic barriers to penetrating these regional markets militate against successful U.S. competition in these regions, U.S. producers and the U.S. government need to cooperate more closely to level the playing field. However, this need must be balanced against the adverse aspects of protectionist legislation. In striking this balance, care must also be taken not to blame an unlevel field for lost market share that is more the result of fundamental noncompetitiveness than trade barriers.

Semiconductor Production Forecast—1989 and 1990

Regional Companies' Semiconductor Forecast—1989 and 1990

The 1989 and 1990 forecast for semiconductor production by regional company base is shown in Table 6-12. This forecast includes captive production. Dataquest forecasts that the demand slowdown discussed in Chapter 5 will cause total production—including captives—to grow almost 16 percent in 1989, but less than 1 percent in 1990.

Table 6-12

Worldwide Semiconductor Production Forecast
Regional Company Share—1988-1990
(Millions of Dollars)

	1988	1989	1990	Market Share 1988	Market Share 1990	CAGR 1988-1990
Worldwide Production						
U.S. Companies	$20,474	$22,213	$23,166	37.7%	38.2%	6.4%
Japanese Companies	26,200	28,189	27,858	48.3%	45.9%	3.1%
European Companies	6,045	7,143	7,465	11.1%	12.3%	11.1%
ROW Companies	1,552	1,997	2,162	2.9%	3.6%	18.0%
Total Worldwide Market	$54,271	$59,542	$60,651	100.0%	100.0%	5.7%
Annual Growth Rate	27.5%	9.7%	1.9%			

Note: Includes captive production

Source: Dataquest
September 1989

Table 6-12 shows the historic erosion of the U.S. companies' merchant plus captive companies' share of worldwide production. However, there are indications that this erosion is slowing. Between 1988 and 1990, U.S. producers have a forecast CAGR of 8 percent. Their share of total production during the period 1988 through 1990 will remain the same at 37 percent.

On the other hand, Japanese companies' share of total production is projected to decline from 47.0 percent in 1988 to 45.0 percent in 1990. Most of this decline can be attributed to price erosion in MOS memories. For the same reason, Japanese companies' total output is forecast at a CAGR of only 3.1 percent through the forecast period.

Regional Production Regardless of Manufacturers' Home Base—1986 through 1992

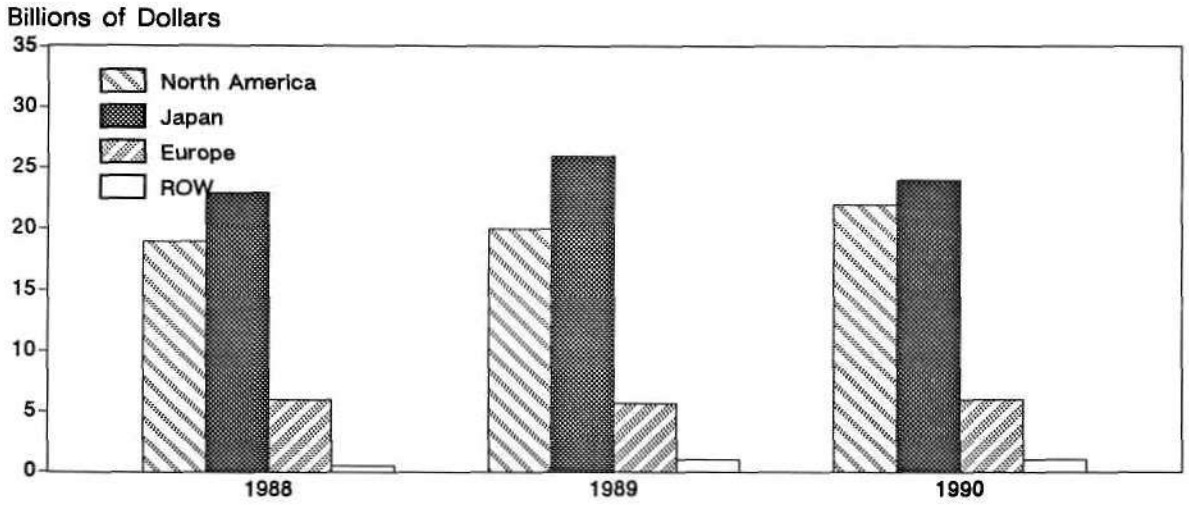
The production forecast of companies headquartered in each of the four regions was given in the previous subsection. However, it also has been indicated that many companies are moving their production facilities to other regions to avoid trade barriers, achieve lowest assembly cost, and get closer to the demand. Examples of this are the fab facilities owned by U.S. and Japanese companies being built in Asian countries such as Singapore and Thailand, and Japanese facilities being built in Europe and the United States.

Therefore, the true semiconductor production within a given region is the total production within the borders of the region, regardless of the home base of the producer. It is this production level that establishes the capital spending within a region and thus establishes the total regional available market for semiconductor manufacturing equipment and materials.

Figure 6-4 shows Dataquest's estimate of such regional semiconductor production from 1986 through 1992. Table 6-13 compares the 1984 regional production share with the 1992 production share forecast. The table shows that in spite of the increase of Japanese and European fab in the United States, its share of worldwide semiconductor production will be approximately 41 percent in 1992, or slightly less than the 43 percent of total production from within Japan's borders.

Figure 6-4

Worldwide Semiconductor Production by Region Regardless of Producers' Home Region



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Source: Dataquest September 1989

Table 6-13

Worldwide Semiconductor Production by Region

	1984	1992
North America	49.8%	40.9%
Japan	38.3	42.8
Europe/ROW	11.9	16.3
Total	100.0%	100.0%

Source: Dataquest September 1989

Four Strategic Issues Regarding the Semiconductor Production Forecast

Impact of Regional Imbalances

Table 6-14 compares the total semiconductor demand (including that of captives) by region with the regional companies' production by regional company base (including captives) for 1986, 1988, and 1990. As the table indicates, the difference between production and demand is net exports. The following conclusions can be drawn from the table:

- As a result of preparations for 1992, Europe is substantially increasing its ratio of production to demand, so European companies' share of the European demand is expected to increase from 58 percent in 1988 to 78 percent in 1990.

- Japan is reversing the historical trend of increasing its ratio of Japanese companies' production to Japanese demand. This ratio peaked in 1988 at 125 percent and should decline to 121 percent by 1990. This again is attributed mostly to MOS memory price declines, but is also because of the increasing share of the European demand being supplied by European companies.
- Asian ROW companies' share of their own market is forecast to increase from 16 percent in 1986 to 29 percent by 1990.
- The major export opportunities for the U.S. companies are the Asian ROW and European markets. The combined demand is forecast to more than double between 1986 and 1990. It is critical that U.S. producers increase their share of both markets for their forecast level of production to be realized. It is also critical that the exchange rate of the dollar against the yen and deutsche mark remain at or below today's levels (less than 140 yen/dollar and 2 deutsche marks/dollar)

Table 6-14

Regional Imbalances in Electronic Equipment Demand and Production—1986, 1988, 1990

Region	Demand Millions of Dollars	Demand Percent	Net Exports Millions of Dollars	Net Exports Percent	Production Millions of Dollars	Production Percent	Ratio of Production to Demand
1986							
North America	$10,843	33.0%	1,965	6.0%	$12,808	39.0%	118.1%
Europe	5,587	17.0	(2,144)	(6.5%)	3,443	10.5	61.6%
Japan	11,855	36.1	2,305	7.0%	14,160	43.1	119.4%
Asian ROW	2,548	7.8	(2,126)	(6.5%)	422	1.3	16.6%
Captive	2,000	6.1			2,000	6.1	100.0%
	$32,833	100.0%	0	0	$32,833	100.0%	
1988							
North America	$16,013	29.5%	2,675	4.9%	$18,688	34.4%	116.7%
Europe	8,492	15.6	(3,503)	(6.5%)	4,989	9.2	58.7%
Japan	20,332	37.4	5,069	9.3%	25,401	46.8	124.9%
Asian ROW	5,655	10.4	(4,241)	(7.8%)	1,414	2.6	25.0%
Captive	3,800	7.0			3,800	7.0	100.0%
	$54,292	100.0%	0	0	$54,292	100.0%	
1990							
North America	$17,643	29.1%	2,762	5.1%	$20,405	33.6%	115.7%
Europe	9,594	15.8	(2,129)	(3.9%)	7,465	12.3	77.8%
Japan	23,060	38.0	4,798	8.8%	27,858	45.9	120.8%
Asian ROW	7,593	12.5	(5,431)	(10.0%)	2,162	3.6	28.5%
Captive	2,761	4.6			2,761	4.6	100.0%
	$60,651	100.0%	0	0	$60,651	100.0%	

Note: Includes captive production

Source: M. Ford and B. Hesley

Opportunities for Semiconductor Producers

Based on the patterns of electronic equipment demand (and therefore, that of semiconductor product categories) outlined in Chapters 4 and 5, the following are the most interesting new product opportunities for the next few years:

- ASICs
- Specialty memories and ferroelectric RAMs (FERRAMs)
- Intelligent power systems
- Microcomponents

ASICs

Although still relatively small today, the ASIC market is forecast by Dataquest to grow at a CAGR of nearly 18 percent through 1992, at which time it should reach sales of more than $13 billion. This forecast is based on the projected growth of the data processing and communications equipment segments, in which most ASICs are used.

Six years ago, the ASIC market was dominated by U.S. producers. Even so, of the top five ASIC suppliers in 1983, Fujitsu ranked as the leader, with slightly more than $100 million in sales, capturing slightly less than one-third of the total market. In 1988, however, Fujitsu, NEC, and Toshiba shared the lead, with AMD and LSI Logic rounding out the top five.

A large part of Japanese ASIC production is consumed by the supplier's parent company and therefore is not available to independent producers. However, the volume and experience gained through the resulting volume production for internal consumption will propel these companies into merchant market dominance.

Much debate occurs as to the relative merits of ASICs as a technology driver versus those of the traditional DRAM. Dataquest believes that DRAMs remain the best vehicle for advancing the absolute limits of line geometry. Memory production provides the best "test pattern" for ensuring the highest levels of productivity and reliability in fab equipment. This relationship between memories, process manufacturability, and fab equipment is paramount in the development of new semiconductor technologies.

FERRAMs and Specialty Memories

Niche memory markets, such as those for FERRAMs or other specialty memories, are providing opportunities for small to medium-size companies. These markets are small, highly specialized, and require less capital investment to penetrate than their huge MOS DRAM/SRAM counterparts.

FERRAMs. FERRAMs are memory devices made from ferroelectric material that essentially merges the benefits of volatile and nonvolatile memory. Ferroelectric material allows the stored information to remain in storage when the power is removed. In volume production, such devices could be less expensive and faster than EEPROMs; their success could displace EEPROM demand.

Dataquest estimates that between 1992 and 1995, FERRAMs will have the potential to capture more than 50 percent of the demand for EEPROMs and therefore constitute a nearly $400 million market.

Specialty Memories. Specialty memories are a specific product category within the general memory segment that Dataquest defines as video RAM, dual-port RAM, battery-powered SRAM, and first-in, first-out (FIFO) SRAM. The aggregate market for these memories—more than $300 million in 1988—is forecast to exceed $500 million by 1990 and $800 million by 1992. This growth represents a 1987 through 1992 CAGR of 33.0 percent, which is higher than that for the MOS memory segment as a whole—23.7 percent. This specialty memory segment is expected to make up 3.0 to 5.0 percent of the total MOS memory segment through 1992. Although the largest part of the specialty segment is occupied by video RAM, which is produced most efficiently by major MOS memory suppliers, the remaining niches within this segment are affording strong growth opportunities for smaller companies and start-ups.

Intelligent Power Devices

Intelligent power devices have been among the fastest-growing segments of the analog product category and have been produced mostly by U.S. companies. Dataquest forecasts that the U.S. benefits from this high-growth area may be short-lived, however, as the dominant consumers of analog and smart power devices increasingly are

becoming consumer equipment producers. Because this equipment segment is dominated by Asian ROW and Japanese equipment producers, Japanese companies that heretofore have stayed away from such analog products should be in a good position to enter this market successfully. Dataquest also notes that U.S. analog producers have as of this date been markedly unsuccessful in selling to Japanese consumer electronics producers.

Microcomponents

The leadership in microprocessors, microperipherals, and microcontrollers has always belonged to the United States. However, at the low end of both the microcontroller and microprocessor segments, the Japanese producers are making strong inroads. For instance, the 8-bit microcontroller market, now dominated by the United States, is expected to fall to Japanese producers because of their expertise in CMOS volume manufacturing and their ability to develop a broad portfolio of specialized products.

In the 16/32-bit microprocessor arena, the United States is expected to remain dominant at the high-performance end of the spectrum. However, as the trend toward reduced-instruction-set computing (RISC) architecture accelerates, opportunity presents itself for the Japanese to gain entry and position with a unique design. Japanese companies are very actively developing their own response to the U.S. standard 32-bit MPUs because they so far have been unsuccessful in obtaining multisource licensing from any U.S. suppliers.

The strongest semiconductor market position that the United States can claim is in this high-end, 32-bit MPU segment. It is critical to the U.S. semiconductor and equipment industries that the United States retain its leadership in such proprietary developments, along with the associated peripheral and support devices.

Capital Spending and Access to Capital Funds

The battle for market share of the total semiconductor demand between regional companies has more importance than receiving a greater share of total revenue in any given year. For U.S. companies that must operate in the highly unforgiving financial environment of the U.S. investment community, market share is the fountainhead of reinvestment. Ultimately, access to investment capital to fund research and development and capital equipment for improving yields or expanding capacity is the lifeblood of long-term survival. Unfortunately, access to requisite investment capital depends more on stellar short-term profit performance in the eyes of the U.S. investment community than on positioning for long-term growth and viability. A key question regarding the future of the U.S. semiconductor industry is whether or not it can obtain the funds to keep up with Japanese capital spending. In dollar terms, the U.S. companies have not kept up with the Japanese since the early 1980s. In yen terms, however, Japanese spending is actually at parity with the spending of U.S. companies.

The Dataquest forecast for regional capital spending by region is shown in Table 6-15. The expected Japanese spending levels exceed those of the United States (in dollars) by almost 50 percent through the forecast period. Thus, Japanese companies had a larger 1988 base of semiconductor production capacity than U.S. companies, and they are adding to that base at a faster pace.

Expenditure by the worldwide semiconductor producers on semiconductor equipment is represented by the capital spending forecast in Table 6-15. This becomes the total available market for the semiconductor manufacturing equipment producers. This demand and corresponding supply of semiconductor manufacturing equipment is the subject of the next chapter.

Avoidance of Government Intervention in Free Trade

The semiconductor production forecast assumes that the dollar exchange rates remain favorable for U.S. exports of both electronic equipment and semiconductor devices. It further assumes that natural market forces will remain in effect and that historical trade barriers to Taiwanese, Korean, and other Asian markets will be lowered. A critical assumption is that of a more favorable balance of trade between the United States and Japan. The objectives of the U.S.-Japan Semiconductor Trade Arrangement of 1986—20 percent penetration of the Japanese market by U.S. semiconductor producers—probably will take several years at its present rate to reach 20 percent share in Japan. In any case, more positive efforts to open the Japanese market must come forth to avoid U.S. government intervention and the associated disruption of the natural market forces upon which the forecast is based.

Table 6-15

Worldwide Semiconductor Production
Regional Capital Spending—1988-1990
(Millions of Dollars)

	1988	1989	1990	Market Share 1988	Market Share 1990	CAGR 1988-1990
Worldwide Capital Spending						
U.S. Companies	$3,339	$ 3,605	$ 3,677	35.8%	35.7%	4.9%
Japanese Companies	4,587	5,183	4,820	49.2	46.8	2.5%
European Companies	926	1,065	1,139	9.9	11.1	10.9%
ROW Companies	468	545	655	5.0	6.4	18.3%
Total Worldwide Spending	$9,320	$10,398	$10,291	100.0%	100.0%	5.1%
Annual Growth Rate	51.9%	11.6%	(1.0%)			
Capital Spending as Percent of Total Production	17.2%	17.5%	17.0%			

Note: Includes captive production

Source: Dataquest
September 1989

CHAPTER 7

Semiconductor Equipment and Materials

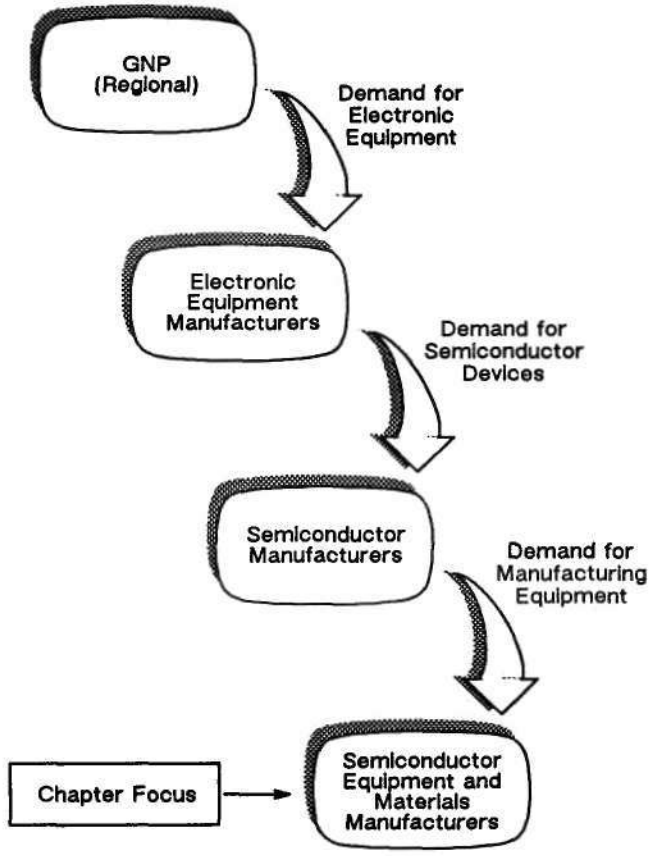
Preceding chapters have discussed the electronics industry infrastructure in terms of a waterfall of demand. The waterfall starts with the demand for electronic equipment, continues with the demand for semiconductor devices, and ends with the demand for semiconductor equipment and materials (see Figure 7-1).

Semiconductor equipment manufacturers and semiconductor materials suppliers are positioned at the bottom tier of the waterfall, as they are the suppliers to the semiconductor manufacturers and the origin of the upstream flow of technology.

This upstream flow of technology creates the higher-performance and lower-cost semiconductor devices that result in superior electronic products. In fact, world leadership in the $760 billion electronic equipment industry requires world leadership in the $54 (merchant and captive)

Figure 7-1

Demand Waterfall



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Source: B. Hesley & M. Ford

semiconductor industry, which in turn depends on world leadership in the relatively small $8 billion equipment market. It is estimated that semiconductor materials of all types represented approximately a $10 billion market in 1988; so together, equipment and materials accounted for nearly $18 billion.

As the preceding chapters have stated, dependency on the source of technology that drives advancing functionality and lower-cost electronic products is so great that regional dominance of specific components of this relatively small industry virtually guarantees regional dominance of the upper tiers of the electronics industry infrastructure.

This chapter is organized into the following subsections:

- Background
  - Discussion of the underlying forces that have created demand for semiconductor equipment and materials
- Key semiconductor materials
- Semiconductor equipment
  - Semiconductor equipment product overview
  - Sources of semiconductor equipment demand
  - Semiconductor equipment demand history and forecast
  - Strategic issues facing the semiconductor equipment industry

Background—Semiconductor Equipment and Materials

Although semiconductor equipment and materials are grouped together in this subsection for discussion, it is important to note that semiconductor equipment demand reflects the capital spending budget of the semiconductor producer, while demand for materials is derived from manufacturing cost. Worldwide and regional demand for equipment thus is determined by the worldwide and regional needs for producers to either implement new technology or expand capacity. As a capital expense, such demand often is modulated by the producers' access to investment capital or the cost of such capital. Regional materials demand is more a function of pure semiconductor production levels within each region. In spite of the different budgets, expenditure, or demand for both equipment and materials within any given region, both depend on and contribute to the success and growth of the semiconductor producers within that region and worldwide.

As Chapter 6 pointed out, the success and growth of semiconductor producers within a region depends on the relative competitiveness of these producers and their corresponding ability to capture share of domestic semiconductor demand as well as that of other regions.

Key Semiconductor Materials

A variety of materials are used throughout the various processing steps of front-end wafer fabrication. These materials include wafer substrates such as silicon and gallium arsenide wafers, photoresist and its corresponding ancillary products, bulk and specialty gases, wet chemicals such as sulfuric acid and hydrogen peroxide, deionized water, metal-source targets for sputtering applications, dielectric coatings such as spin-on glass and polyimides, and liquid and solid dopant sources. This part of our discussion will focus briefly on the products, suppliers, and factors that characterize the markets of three of the key materials used in the manufacture of semiconductor devices: silicon wafers, photoresist, and semiconductor gases.

Silicon

Silicon is the second most abundant element in the earth's crust. It occurs in the form of oxides, or silicates such as silica (sand). In the 1950s, silicon was considered to be one of several materials with semiconductor potential. With the development of planar processing in 1960, polysilicon price reductions, and inexpensive plastic silicon transistor packaging, silicon superseded germanium in the market and today is the dominant substrate used in semiconductor device manufacture. As such, it is an excellent indicator of the level of manufacturing activity within a given wafer fabrication environment.

Products

Silicon wafers are thin slices of single-crystal silicon cut from a cylindrical ingot and then polished. The growth of a single-crystal ingot from polycrystalline silicon is controlled to produce wafers with a well-defined diameter, typically 3 to 8 inches.

A second category of silicon wafers is epitaxial wafers. Epitaxial processing produces a layer of single-crystal material that has the same crystallographic orientation as the underlying wafer substrate. It is possible to design the epitaxial layer to meet well-defined chemical, physical, and electrical specifications.

Dataquest estimates that the world merchant silicon and epitaxial wafer market was $2.17 billion in 1988.

Silicon Suppliers

Companies that produce silicon and epitaxial wafers are defined either as merchant silicon companies or captive silicon producers.

Merchant Silicon Companies. The vast majority of silicon consumed today is provided by merchant silicon suppliers. It is interesting to note that all major merchant silicon companies in the world today have large corporate parents. This provides a cash flow buffer against downturns in the business cycle, as well as a source of funding for new facilities and capacity expansions. In today's competitive business environment, it is unclear whether or not a standalone entrepreneurial silicon operation could compete and survive against the major silicon suppliers with their extensive financial backing from corporate parents.

Captive Silicon Producers. Silicon also is produced to a lesser extent by both merchant and captive semiconductor manufacturers. These semiconductor manufacturers are referred to collectively as captive silicon producers because they grow single-crystal silicon to produce wafers for their own internal consumption.

Semiconductor manufacturers with captive silicon production tend to be established, vertically integrated companies. In the early years of the semiconductor industry, the high cost of silicon provided sufficient economic justification for some semiconductor manufacturers to develop this internal capability. Today, however, high-quality, low-cost silicon wafers are readily available from a number of merchant silicon companies. Nevertheless, one benefit of retaining captive silicon production activities is that a semiconductor company can manufacture wafers with custom and proprietary specifications. In addition, captive silicon producers in the United States can ship silicon material to their facilities in Japan and Europe, thereby avoiding those regions' relatively higher wafer costs resulting from currency appreciation over the last several years.

Factors that Characterize the Silicon Wafer Industry

Two significant factors characterize the silicon wafer industry of the last several years. These factors are wafer pricing pressures and industry consolidation.

Wafer Pricing Pressures. Dataquest believes that wafer pricing pressure has been one of the major factors that has affected profitability in the silicon industry during the last several years. Historically, as large wafer products mature, prices decrease because silicon wafer companies move down the learning curve of wafer manufacturing. Pricing has been an important competitive issue as well.

During the downturn of the business cycle between 1985 and 1987, however, there were additional pressures from cost-conscious semiconductor manufacturers for lower prices. At the same time, increasing device complexity led to demands for tighter wafer specifications. This, in turn, meant that silicon companies have had to perform more analytical tests to ensure wafer quality. More analytical testing and product qualification mean higher costs to the silicon companies, and, with the continued downward pricing pressures, silicon companies have been forced to accept smaller margins on their products.

During the healthy market environment of 1988, merchant silicon companies experienced some relief from the downward pricing pressures of previous years. This trend has allowed some silicon companies to return to profitability after several years of losses. Dataquest believes that a favorable and stable wafer pricing environment is essential in order to avoid severe profitability problems in the silicon wafer industry in the future.

Industry Consolidation. There have been a series of six acquisitions of merchant silicon and epitaxial wafer companies since 1985 (see Table 7-1). In the majority of these acquisitions, the new corporate parent was already active in the silicon wafer industry prior to its acquisition of its new silicon company. These acquisitions illustrate the dynamics of consolidation in a maturing industry.

As seen in Table 7-1, five of the six acquisitions consisted of U.S. silicon companies being acquired by Japanese or West German corporations. The two most recent acquisitions, in particular, had a significant impact on the worldwide market share of U.S.-based silicon suppliers by reducing their share to less than 2 percent of the worldwide merchant wafer market. This situation has raised several important concerns. With the United States' loss of all control over the production of merchant silicon wafers, are its semiconductor manufacturers at a disadvantage in the development of next-generation integrated circuits? Will silicon operations under foreign ownership be fully responsive to the needs of U.S. semiconductor manufacturers?

Clearly, other countries already have decided that silicon is a crucial strategic material. Most of the new entrants in the merchant silicon wafer market over the last several years have come from outside the United States—notably from Japan, Europe, and the Pacific Rim. In these countries, the short-term rigors of the silicon wafer market are endured as part of a long-term strategy for survival in the electronics industry.

Photoresist

Photoresist is a light-sensitive, polymer-based material applied to wafers during semiconductor fabrication to transfer the circuit pattern from a mask to the underlying substrate. Photoresist is applied to the wafer at every mask level during the fabrication process; the number of mask levels correlates with device complexity.

Products

Resists used in semiconductor device fabrication typically are classified into four different categories that reflect the sensitivity of the resist to a given type of light or radiation. The four categories are optical, deep-UV, e-beam, and X-ray resists.

Resists are characterized as positive- or negative-working materials. The basic difference between a positive and a negative resist depends on the material's response to light or radiation. A positive resist leaves behind an image on the wafer that matches the pattern on a mask, while a negative resist leaves behind an image that is the reverse of the mask pattern.

In addition to the resist material itself, there is an associated class of chemicals known as resist ancillary products. These include developers, rinses, dyes, strippers, thinners, adhesion promoters, and etchants. The developers, in particular, are closely designed to complement a given resist formulation in order to optimize resist performance.

Almost all resist materials used in semiconductor device fabrication today are optical photoresists. Dataquest estimates that the 1988 world market for optical photoresist was approximately $220 million.

Table 7-1

Recent Acquisitions in the Silicon Wafer Industry

Acquisition Announced	Company	Acquired By
1988	Monsanto Electronic Materials Company (U.S.)	Huels AG (West Germany)
1988	Cincinnati Milacron (U.S.)	Osaka Titanium Co. (Japan)
1987	Dynamit Nobel Silicon (Italy)	Huels AG (West Germany)
1986	U.S. Semiconductor (U.S.)	Osaka Titanium Co. (Japan)
1986	Siltec Corporation (U.S.)	Mitsubishi Metal (Japan)
1985	NBK Corporation (U.S.)	Kawasaki Steel (Japan)

Source: Dataquest
September 1989

Photoresist Suppliers

Typically, photoresist companies are part of larger chemical or electronic materials corporations. Four major companies dominate the world's optical photoresist market today: One is Japanese-based, two are U.S.-based, and one is European-based. The major Japanese photoresist supplier historically has focused on its home market of Japan. In contrast, the two major U.S. suppliers and the major European photoresist company have a well-established presence in all three of the major processing regions of the world: Japan, the United States, and Europe. This has been achieved through overseas photoresist operations (including manufacturing plants) and joint ventures.

Export Market Strategies. Dataquest has observed that when Japanese semiconductor manufacturers set up new fab facilities outside of Japan, often these new fabs are designed to duplicate an existing line in Japan. These include not only products and process technology, but also fabrication equipment and semiconductor materials. This strategy allows the semiconductor manufacturer to bring the new fab line up to speed in a very short period of time.

This practice has particular significance for Japanese photoresist suppliers, which historically have had only minimal participation in export markets such as the United States or Europe. Because photoresist is such a complex chemical system, Dataquest believes that it will be a high priority with Japanese semiconductor manufacturers to use the same resist for their new fab facilities outside of Japan as in their current fabs in Japan. Therefore, Japanese resist companies now have a well-defined avenue to expand their export market opportunities.

Factors that Characterize the Photoresist Industry

Several factors and issues characterize today's photoresist industry, including the following:

- Photoresist is closely tied to lithography, the technology driver for manufacturing higher density integrated circuits.
  - As semiconductor manufacturers continue to push the limits of submicron processing, it is clear that the lithography process must be considered as a single system. This system includes the device process technology, the lithography equipment, lenses, and sources, as well as the photoresist material itself.
  - Dataquest believes that joint development and exchange programs between semiconductor companies, equipment vendors, and photoresist manufacturers will be essential in the development of advanced submicron processes.
- One of the major issues facing semiconductor manufacturers today is to determine what strategy will be adopted for 0.5-micron device processing expected in production in the mid-1990s.
  - Currently, several lithography alternatives exist including g-line steppers, i-line steppers, excimer laser steppers, step-and-scan lithography, or X-ray lithography. Right now, however, there is no clear consensus of opinion.
  - For photoresist manufacturers, this also is a key issue because few companies have sufficient R&D funds to develop new resist formulations for all lithographic alternatives. Photoresist companies today are faced with deciding where to focus their R&D efforts, ever mindful that different regional semiconductor manufacturers may well pursue different lithography strategies.
- Photoresist is perceived by the customer to be a technology-driven product because the material's performance is closely tied to lithography processing.
  - Therefore, photoresist suppliers have not experienced the same level of downward pricing pressure as in other electronic material categories.
  - Pricing—for optical positive resist, in particular—has remained fairly stable or experienced a modest increase as new resist formulations are developed for the processing of smaller line geometries.

Semiconductor Gases

Products

Semiconductor gases generally are divided into two product categories: bulk and specialty gases.

Bulk Gases. The bulk semiconductor gases are nitrogen, oxygen, hydrogen, and argon. The "bulk" designation typically refers to a discrete delivery of a large volume of gas by truck transport. These gases typically are delivered as cryogenic liquids because of the efficiency of transportation and storage prior to the vaporization stage at the semiconductor manufacturer's facility. In addition to cryogenic liquid delivery, nitrogen gas also is provided through direct pipeline delivery, as well as at customer on-site nitrogen-generation plants.

Specialty Gases. A large number of gases (more than 35) are classified as semiconductor specialty gases. For that reason, a further segmentation of this category is necessary and is based on the chemical reactivity and functionality of the various specialty gases. Dataquest segments the specialty gas market into six categories: silicon-precursor gases, dopants, etchant gases, reactant gases, atmospheric/purge cylinder gases, and others. Specialty gases are used in comparatively smaller volumes than bulk gases; thus, they are delivered in high-pressure cylinders.

Dataquest estimates that the 1988 world market for semiconductor bulk and specialty gases was approximately $870 million.

Semiconductor Gas Suppliers

Several factors will dictate the success of a gas company supplying the semiconductor industry. These include an extensive distribution network, some level of primary manufacturing capability, and a strong service organization.

Five companies and their associated operations dominate the world's semiconductor gas industry today. These major suppliers of semiconductor gases have a good-to-strong presence in the four major semiconductor production regions of the world: Japan, the United States, Europe, and the Pacific Rim. This presence is achieved through overseas operations, equity investment positions in foreign gas companies, or technical/marketing agreements.

For the major gas suppliers, the semiconductor gas market represents only a small portion of a company's total gas business activities. Some of the nonsemiconductor gas applications that represent far larger market opportunities include nitrogen for frozen food processing, oxygen for steel processing, and hydrogen for fuel cells in the rocket and aerospace industries. However, the semiconductor industry represents probably the most rigorous demands on gas suppliers with regard to providing high-purity materials and delivery systems. Therefore, success in the semiconductor gas industry promotes a gas supplier's presence at the cutting edge of gas technology.

Factors That Characterize the Semiconductor Gas Industry

Several unique factors characterize the semiconductor gas market, including the following:

- The specialty gas companies are unique when compared with other electronic materials companies that sell products to the semiconductor industry. What makes this market different is that no one specialty gas company has primary manufacturing capability for all of the specialty gases that it provides to the industry. Thus, a specialty gas company typically must buy some of its products from a competitor.

- Nitrogen is consumed by the semiconductor industry in substantially larger volumes than any other gas, and accounts for approximately 80 percent of semiconductor bulk gas sales. While bulk and specialty gas usage typically tracks with semiconductor device production levels and the consumption of silicon wafers, nitrogen also is used to maintain the integrity of processing equipment whether wafers are being processed or not. This means that the nitrogen market, unlike other electronic materials, is very stable even during the times of low production associated with downturns in the semiconductor business cycle.

- The semiconductor bulk gas industry is characterized by long-term contracts between vendor and customer because of the support equipment required at the customer's site for the on-site storage of bulk gases. Typically, one bulk gas supplier supports each fab facility, and that company often will receive the initial gas contract before construction even begins on a new fab. In contrast, the specialty gas industry is characterized by short-term contracts and an ongoing competitive market environment. Multiple specialty gas vendors per fab is the norm rather than the exception.

Background—Semiconductor Equipment

Initially, in the 1950s and 1960s, because there was no commercial source for semiconductor equipment, such equipment was built for internal use by semiconductor producers such as AT&T, IBM, Motorola, and Texas Instruments. In the late 1960s and 1970s, merchant semiconductor equipment manufacturers began to provide equipment to world semiconductor producers. In the beginning, most of the companies were of U.S. origin, with the Japanese and European equipment manufacturers following somewhat later. Major semiconductor companies began to depend on merchant semiconductor equipment suppliers, and equipment that was internally supplied by semiconductor producers began to decline. Thus, the merchant semiconductor equipment industry is approximately 20 years old, and it is interesting to note that several of the world's major equipment manufacturers celebrated their 20-year anniversaries in 1988.

The demand for semiconductor equipment in Japan was fueled by the rise of the Japanese semiconductor industry in the early 1970s, and this demand was met by two sources. The first was the rise of the indigenous Japanese equipment industry, and the second was the transfer of equipment technology to Japan from the United States. U.S. equipment manufacturers, in an effort to penetrate the fast-growing Japanese equipment market, provided Japanese equipment manufacturers access to U.S.-developed technology. By the late 1970s and early 1980s, Japanese equipment companies emerged as merchant suppliers, providing crucial technologies for new VLSI devices manufactured by the fast-growing Japanese semiconductor companies. In 1988, Japanese wafer fab equipment companies shared 5 of the top 10 places in the ranking of worldwide wafer fab equipment suppliers. In terms of world market share for wafer fab equipment, Japanese equipment companies and U.S. equipment suppliers have essentially equal market shares. In certain equipment categories (for instance, lithography) Japanese equipment makers clearly dominate the world market.

Semiconductor Manufacturing Equipment—Product Overview

The equipment used for the production of semiconductor devices is divided into two major segments: wafer fabrication (front end) equipment and assembly and test (back end) equipment.

Wafer fab equipment is the very sophisticated capital equipment used to manufacture IC devices on the silicon wafer. Front-end, or wafer fab, equipment includes those crucial technologies required for manufacturing critical VLSI devices such as 4Mb and 16Mb DRAMs, 32-bit and larger microprocessors, and advanced logic devices.

IC manufacture, or the wafer fabrication process, takes place in a special ultraclean facility called the fab or clean room. Bare silicon wafers are the input material to the wafer fab; finished silicon wafers are the output of the fab. In many cases, each wafer contains hundreds of manufactured ICs.

The finished wafer then is sent to the assembly and test facility, where the wafer is cut up into individual ICs. The good ICs are separated from the bad; the good ICs are then assembled and packaged and each packaged IC tested. Generally, the wafer fabrication facility and the assembly and test facility are separate; in many cases, the latter facility may be located in another country.

Technical advances in wafer fab equipment directly affect advances in manufacturing ICs. This means that more sophisticated ICs with more functionality or higher speeds or both can be manufactured. As more sophisticated ICs become available, more advanced electronic equipment becomes available, forging a direct link between wafer fab equipment and advanced computers and telecommunications equipment. Thus, technology leadership in the relatively small $5 billion worldwide wafer fab equipment market is the gateway to leadership in the $760 billion worldwide electronic equipment market. In addition, the semiconductor company that uses the latest wafer fab equipment will have a competitive advantage in the IC market.

As more sophisticated ICs are manufactured, more sophisticated assembly and test equipment must be developed; in conjunction with the advances in equipment, advances must be made in semiconductor materials as well. However, the driving force in semiconductor manufacturing is wafer fab

equipment, or the ability to manufacture the advanced IC itself. This is the area that tends to drive advances in materials as well as in assembly and test equipment. For this reason, the remainder of this chapter will focus on wafer fab equipment. This is not to minimize the strategic importance of semiconductor materials and assembly and test equipment, but rather to recognize that technology leadership in wafer fab equipment is more closely linked with leadership in the huge electronic equipment market.

Of the total amount of capital spending by the world's semiconductor manufacturers, approximately 80 percent is spent on front-end and back-end equipment; of this amount, 60 percent is spent on wafer fab equipment. Thus, wafer fab equipment represents approximately 50 percent of the spending by the world's semiconductor producers and reached almost $5 billion in 1988.

Wafer fabrication equipment is divided into 11 major categories, 8 of which are briefly described in the following paragraphs. This equipment is used to perform the approximately 400 steps required to make an advanced IC. In its simplest description, the IC wafer fabrication process can be divided into three basic operations: thin films are deposited on the silicon wafer, the deposited films are patterned, and the film characteristics are altered.

Lithography

If wafer fab equipment is the driving area for IC production, lithography is the very heart and core of advanced IC manufacturing technology. Lithography is the engine that drives all other technologies used in IC manufacturing. It is the critical patterning technology for VLSI devices because it is the technology enabler for fine-line geometries. The term fine-line geometry refers to the minimum geometries of semiconductor devices. The finer the geometry, the more transistors the IC designer can put on a chip or the more functionality the chip has. For instance, a 1Mb DRAM, which has more than 1 million transistors on the chip, is fabricated with minimum feature sizes of approximately 1.2 micron (the diameter of a human hair is 100.0 microns). Advances in lithography tools now allow 0.8-micron feature sizes to be produced on the chip. With this finer feature size, 4Mb DRAMs containing more than 4 million transistors can be produced. Currently, advanced lithography tools can pattern lines as small as the 0.5-micron feature sizes required for 16Mb DRAMs. Finer geometries also mean that faster chips can be produced, which are essential for building ever-faster computers.

Lithography equipment includes contact and proximity aligners, scanning projection aligners, steppers (reduction and 1:1), e-beam systems, X-ray aligners, and the recently announced step-and-scan aligner, each of which is described briefly as follows:

- Contact/proximity aligners—the industry's first lithography tools, which reach back to the very beginnings of the semiconductor industry—have declined. Today, they are a $21 million niche market. This product is not likely to play a major role in the future lithography market.
- Scanning projection aligners superseded contact/proximity aligners to become the dominant lithography tool for many years. However, this tool is limited in its ability to pattern fine features, and it eventually gave way to steppers.
  - Projection aligners reached their peak in 1984 and 1985 and have since declined to a $159 million market in 1988, representing only 13 percent of the total world lithography market of $1,219 million.
  - More than 3,000 of these aligners are in the field, and this base of aligners will continue to grow slowly to provide additional capacity in existing fabs. However, the newer advanced fabs are not being outfitted with scanning projection aligners.
- Steppers, because of their inherent ability to pattern finer features than scanning projection aligners, have become the dominant and state-of-art lithography tool.
  - In 1988, steppers accounted for $903 million, or 74 percent, of the total lithography market. Steppers probably will continue to dominate the lithography market for several years.
  - Today, all advanced ICs are fabricated using steppers, and production-worthy steppers in the most advanced fabs can pattern 0.7-micron features. Advanced excimer laser steppers that can pattern 0.35-micron features are under development.

  - Steppers have a solid technology grasp on the lithography market, but it could be weakened by the recent advent of the step-and-scan aligner.

- The potential of the step-and-scan aligner, which was recently introduced to the marketplace, is still uncertain.
  - If successful, step-and-scan systems could compete with steppers and erode their market share.
  - This aligner is a hybrid system that combines the best of both scanning projection technology and stepper technology. It currently appears to be the most advanced aligner on the market, but because it is a new system, field experience is not yet available.
  - This aligner can pattern 0.5-micron features with a wafer throughput that excels steppers, and it is the dark horse in the lithography race.
- E-beam lithography systems have two niche applications.
  - E-beam is the technology used by the worldwide maskmaking industry to produce the masks and reticles required by semiconductor manufacturers for their projection aligners and steppers.
  - E-beam also is used to "direct write" a wafer in special instances, such as quick-turn IC prototyping and small quantity ASIC devices.
  - Together, these two niche markets accounted for $116 million of the 1988 lithography market. However, because of its very low productivity and high cost per wafer, e-beam is not likely to be a mainstream lithography technology, although it can pattern finer geometries than steppers.
- The world semiconductor manufacturers have essentially ignored X-ray aligners (the 1988 market was $10 million) in spite of the numerous advantages of X-ray aligners over conventional optical aligners such as steppers.
  - The semiconductor industry is very slow to accept new technologies, and because the stepper manufacturers continue to make advances in stepper technology, the market window for X-ray aligners continues to be pushed out.
  - Presently, there are X-ray aligners on the market that can pattern 0.5-micron features and less. These aligners are standalone systems and resemble conventional steppers; it is uncertain just how much less than 0.5-micron they can be used in a production environment.
  - However, considerable worldwide development is under way on another type of X-ray technology called synchrotron orbital radiation (SOR) that will have a production limit of approximately 0.2 micron.
    - The Japanese are making very heavy investments in this technology.
    - In addition, IBM already has invested $500 million in SOR and expects to spend $1 billion by the time the system is fully developed.

In summary, steppers are the dominant tool today and will continue to be the dominant tool until the industry reaches 0.5-micron feature sizes, probably by the mid-1990s. At that point there are several competing technologies, and currently it is not clear which technology will be dominant. The dominant technology may very well continue to be steppers, but we must wait for further developments before reaching more secure predictive ground.

Automatic Photoresist Processing Equipment

Automatic photoresist processing equipment, or track equipment as it is commonly known, is used to apply and process the photoresist film that is temporarily applied to the wafer to allow patterning of the wafers by the lithography equipment. The main technical objectives of track systems are to deposit the thin photoresist coatings prior to the patterning process that takes place in the lithography tool and to develop the photoresist after patterning.

Track equipment includes wafer clean/bake, wafer prime, coat/bake, develop/bake, and photoresist stabilization equipment. Track equipment is used in the lithography cell of the wafer fab and actually can be considered part of the lithography process. Because of this, the demand for track systems is closely tied to lithography demand and has about the same compound annual growth rate (CAGR). In 1988, the demand for track equipment reached $250 million.

Etch and Clean

This segment includes wet process, dry etch, dry strip, and ion milling equipment. Wet processing, so-called because ultrapure water and liquid chemicals are used in the process, is used throughout the wafer fab for the cleaning and wet etching of wafers. Wet processing goes back to the early days of the semiconductor industry. Etching, along with lithography and track equipment, is another of the equipment technologies that is part of patterning thin films on the wafer.

Wet etching is used for patterning relatively large features on the wafer, while dry etching, the newer technology, is used almost exclusively in the fabrication of advanced devices that require fine-feature patterning. As advances in lithography equipment allow finer features to be patterned on the wafer, concomitant advances in dry-etch equipment need to be made to fully implement the fine-pattern features on the wafer.

Dry-strip equipment is used to remove the photoresist films that are temporarily applied to the wafer to allow patterning. The total etch-and-clean market was $880 million, of which $235 million was for wet-process equipment, $547 million was for dry-etch equipment, and $90 million was for dry-strip equipment.

Deposition

Deposition includes several technologies that are used to deposit thin films on the wafer. The three major technologies included in this category are chemical vapor deposition (CVD), physical vapor deposition (PVD), and epitaxy. Epitaxy technology includes silicon epitaxy, metalorganic CVD, and molecular beam epitaxy equipment. Once these films are deposited by any of three major techniques, they are patterned with the aid of the lithography, track, and etch equipment previously described.

CVD equipment generally is used to deposit insulator films on the wafer, while PVD is used to deposit the aluminum films that are required to wire-up, or connect, all of the transistors on a chip (more than 4 million transistors are used, for example, in the case of 4Mb DRAMs). Collectively, CVD and PVD equipment is used to fabricate the interconnect portion of the chip. As with advances in lithography, advances in CVD and PVD equipment need to made in order to keep up with current technologies. When new advanced steppers are introduced that have ever-smaller fine-pattern capability, it sets off a new round of development in CVD and PVD equipment (as well as in other front-end equipment); CVD and PVD manufacturers then must struggle to keep pace. For instance, the equipment and technology required to interconnect the more than 4 million transistors of a 4Mb DRAM are vastly more sophisticated (and costly) than was required for the 65,000 transistors of a 64K DRAM of a few years ago. In the past, the portion of chip fabrication cost that was attributed to chip interconnection was small. With advanced chips that have several levels of interconnection on the chip, the cost of interconnection can be 50 percent or more of the entire wafer fabrication cost.

In 1988, the total deposition market was $983 million; CVD accounted for $455 million of this market, PVD for $315 million, and total epitaxy for the remaining $213 million. There is currently a tremendous amount of activity in both the CVD and PVD technology areas as new equipment is being introduced to fabricate the most advanced ICs. The CVD market grew phenomenally from $254 million in 1987 to $455 million in 1988.

In PVD equipment, attention is being directed toward integrated processing systems that will be able to handle several process steps in one piece of equipment instead of having to move the wafer to several pieces of equipment to accomplish the same number of process steps. Generally, as advance chips need to be manufactured, the semiconductor industry will move to more integrated manufacturing. This eliminates human handling of the wafers, decreases contamination, and increases yields.

We said previously that lithography essentially drives the other technologies used in the fabrication of a wafer. Although lithography tools are well on the path to fine-line patterning, work still needs to be done in the deposition of thin films, either by CVD or PVD.

Diffusion Furnaces

Diffusion furnace equipment includes both horizontal and vertical tube furnaces. These high-temperature furnaces are used to incorporate precise quantities of impurities, or dopants, into the deposited films on the wafer in order to control the electrical properties and, hence, the performance of the IC. Other applications include the growing of oxide films, the deposition of insulator films, and annealing.

Horizontal tube furnaces, the workhorses of the industry since their inception, have been losing ground to other technologies such as ion implantation and CVD equipment. For advanced devices, ion implantation now is the preferred method of introducing impurities into the wafer, and CVD is the preferred technology for film deposition. Although the number of horizontal furnaces has declined substantially since the technology's peak a few years ago, ASPs have risen to the extent that horizontal furnace sales reached a record $243 million in 1988.

Vertical furnaces are an emerging technology. Vertical furnaces have several advantages over horizontal furnaces, particularly for advanced devices, and they are being rapidly accepted in Japan. Some advantages include lower power consumption, smaller space requirements, easier automation, and excellent technical performance. In the past, only horizontal furnaces were used in the fab, but the Japanese expect vertical furnaces to be the dominate furnace technology of the future. In other regions of the world, vertical furnaces have been given a lukewarm reception. Vertical diffusion furnace sales were $23 million in 1988.

Rapid Thermal Processing

Rapid thermal processing (RTP) is a high-temperature technology that was expected to supplant the annealing process of diffusion furnaces. However, this equipment has not found its way into the production mainstream of the wafer fab for this application because anneals done on diffusion furnaces are superior to RTP anneals. RTP is beginning to find opportunities in other applications in the wafer fab, such as in the thin-film area, but these are still emerging. In 1988, the RTP market amounted to $22 million.

Ion Implantation

In the past, introduction of impurities into the thin films on the IC was done in diffusion furnaces, but diffusion furnaces are inadequate for advanced devices that have fine features. Ion implanters provide a much more precise control of the amount, location, and depth of the impurity into the thin film. Implanters are classified as medium current or high current, depending on the amount of impurity that can be incorporated quickly into the film. High-voltage implanters also can incorporate impurities to a greater depth in the film than can either medium- or high-current implanters. It is interesting to note that implanters are essentially linear accelerators and have their roots in that technology. In 1988, the total world market for implanters was $379 million.

Diffusion furnaces, rapid thermal processing equipment, and ion implanters all are used in the wafer fabrication process essentially to modify the thin films that were deposited and patterned by the other equipment technologies described previously.

Critical Dimension/Wafer Inspection

Critical dimension (CD) and wafer inspection equipment are two types of process control equipment. Process control equipment is used to verify the wafer fabrication process rather than contribute to the actual fabrication of the IC. CD equipment is used to measure the features on the wafer to ensure that the patterning process is indeed doing what it is supposed to do. Wafer inspection equipment is used to check for defects on the wafer. Both CD and wafer inspection equipment have a tremendously wide variance in price, depending on the level and sophistication of operator automation. Systems may range from $50,000 for a low-end manual system to $1.2 million for a fully automated advanced system.

CD and wafer inspection equipment technology also is driven by advances in lithography. As finer and finer features are fabricated on the IC, it becomes necessary to measure smaller and smaller features with greater accuracy and precision. Also, as feature sizes get smaller, it becomes necessary to check for ever-smaller defects, and to identify new types of defects. In 1988, the combined markets for CD and wafer inspection equipment totaled $173 million.

Sources of Semiconductor Equipment Demand

The two fundamental sources of demand for semiconductor production equipment are as follows:

- Semiconductor producers purchase advanced equipment to increase competitiveness by decreasing manufacturing cost through advanced manufacturing technology.
- Semiconductor producers purchase equipment to expand production capacity.

Advanced Manufacturing Technology Increases Competitiveness

The primary driving force for new semiconductor equipment for the next two to three years will be the need for advanced manufacturing technology. As mentioned previously and discussed fully in Chapter 6, the success and growth of semiconductor producers within a given region depend ultimately on their relative competitiveness. This competitiveness is determined by regional economic factors such as cost of labor, cost of capital, and availability of patient capital, but it ultimately is reduced to relative product quality and manufacturing costs.

Thus, relative competitiveness depends on the following:

- Efficiency—Higher yields provide lower cost per device.
- Fast turnaround—The earlier a producer gets to market and moves down the learning curve, the more costs become lower and remain lower than those of competitors that enter the market later.
- Higher quality and reliability—The quality and reliability of devices are more important to the device user than the absolute price.

Semiconductor equipment demand based on upgrading competitiveness through manufacturing technology therefore is driven by these factors. Key manufacturing technologies that contribute to these factors are those that contribute to smaller feature sizes, higher productivity, and reduced contamination. Smaller feature sizes provide increased functions per die, higher speeds, and increased die per wafer. Higher productivity translates into more ICs manufactured per time period, and reduced contamination contributes to higher yields, or more good die per manufacturing run.

Another key manufacturing parameter is turnaround, or cycle time, which is the length of time it takes to fabricate a wafer. A producer with shorter cycle times than its competitor moves down the learning curve faster because it is able to correct the IC fabrication process when necessary in a shorter interval of time. As the producer moves down the learning curve, its manufacturing costs decline with a concomitant competitive advantage. Therefore, the key technology demand drivers for manufacturing equipment are all related to the front-end process. Table 7-2 shows the worldwide wafer fab market for 1988 by equipment segment.

Table 7-2

1988 Worldwide Wafer Fab Equipment Demand (Millions of Dollars)

Equipment	Demand
Lithography	
Contact/proximity	$ 21
Projection aligners	159
Steppers	903
Direct-write e-beam	68
Maskmaking e-beam/laser	59
X-ray	9
Total Lithography	$1,219
Automatic Photoresist Processing Equipment	$ 250
Etch and Clean	
Wet process	$ 235
Dry strip	90
Dry etch	547
Ion milling	8
Total Etch and Clean	$ 880
Deposition	
Chemical vapor deposition	$ 455
Physical vapor deposition	315
Silicon epitaxy	85
Metalorganic CVD	43
Molecular beam epitaxy	85
Total Deposition	$ 983
Diffusion	$ 266
Rapid Thermal Processing	$ 22
Ion Implantation	$ 379
CD/Wafer Inspection	$ 173
Other Process Control	$ 427
Factory Automation	$ 130
Other Wafer Fab Equipment	$ 166
Total Wafer Fab Equipment	$4,895

Source: Dataquest
September 1989

Capacity Utilization Drives Capacity Expansion

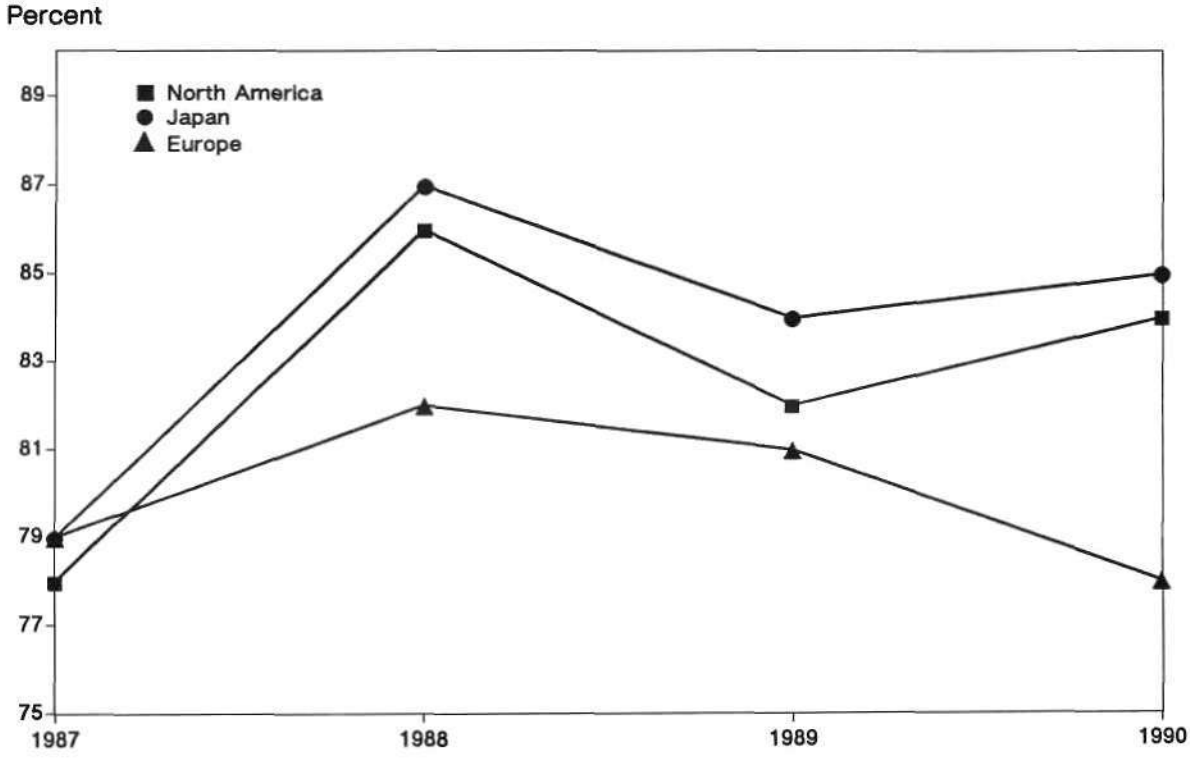
The second driving force behind equipment demand is the requirement to increase production capacity. As regional producers realize success and growth through superior relative competitiveness, they use up existing production capacity and must invest in capacity expansion. Therefore, not only does the semiconductor equipment supplier contribute to the growth and success of the semiconductor producer by improving competitiveness, the producer's success fuels the growth and success of the supplier as well.

Figure 7-2 presents regional capital utilization by regional company base for North America, Europe, and Japan. Table 7-3 compares historical worldwide merchant semiconductor production with worldwide capital spending and wafer fab equipment demand.

In a time of rapidly expanding demand for semiconductors, the demand for equipment surges. This is illustrated by the boom period of 1983 and 1984, as producers in all regions eagerly expanded capacity in response to the buoyant PC-driven semiconductor demand forecast. This resulted in a capacity utilization and equipment demand peak in 1984, as shown in Figure 7-2 and Table 7-3. The subsequent collapse of semiconductor demand in the following two years resulted in a severe downturn of equipment demand as capacity utilization plummeted.

Figure 7–2

Estimated Regional Semiconductor Capacity Utilization 1987-1990



Source: Dataquest September 1989

Table 7-3

Worldwide Electronic Equipment and Semiconductor Consumption
1987-1988
(Includes Captive Suppliers)

	1987	1988	CAGR 1987-1988
Electronic Equipment Production	$650.8	$760.0	
Semiconductor Production	$ 41.5	$ 54.1	30.4%
Capital Spending ($B)	$ 6.4	$ 10.0	56.3%
Capital Spending Annual Growth	25.5%	56.1%	
% of Production	15.4%	18.5%	
Front End Equipment Demand ($B)	$ 3.1	$ 4.9	58.1%
% of Capital Spending	48.4%	49.0%	
Annual Growth of Equipment Demand	14.8%	58.1%	

Source: Dataquest
September 1989

The strong recovery of semiconductor demand from 1987 through the present has generated higher demand for production equipment. Table 7-3 shows that the worldwide demand for semiconductor front-end equipment has increased 58 percent in 1988 over 1987. However, as the next paragraphs will show, most of this growth in equipment demand in the 1987 through 1989 period was for competitiveness improvement rather than capacity expansion, because only now are utilization rates beginning to exceed those of the boom years. Table 7-3 also illustrates that 49 percent of the total capital spending by semiconductor manufacturers is spent on wafer fab equipment. Dataquest estimates that the balance of the spending goes to purchase back-end equipment (31 percent) and property and facilities (20 percent).

Regional Demand History 1984 to 1988

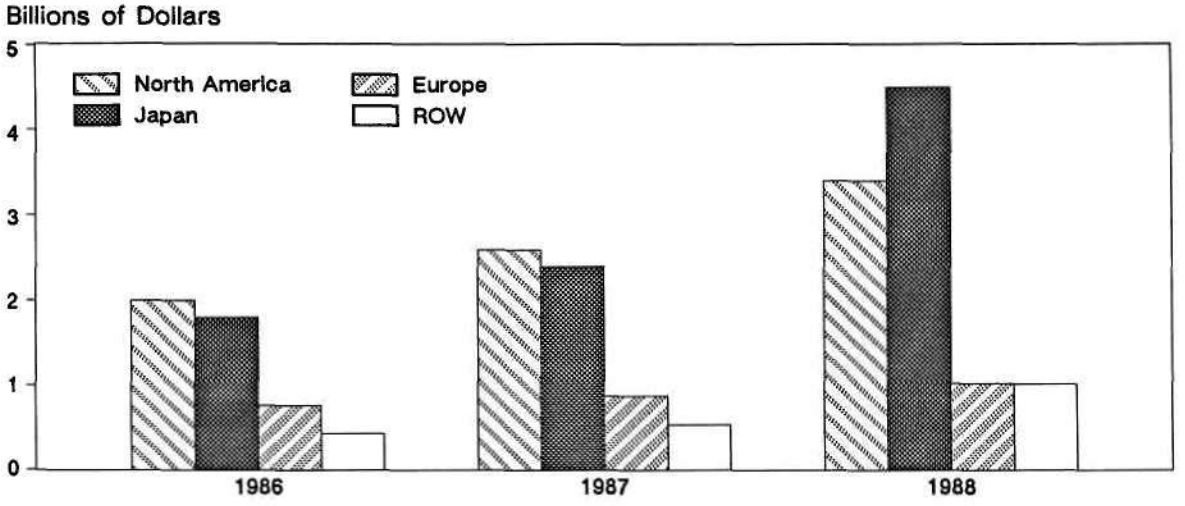
Figure 7-3 illustrates the regional capital spending of merchant and captive producers regardless of nationality. This represents the regional total available market for goods purchased from such capital expenditure.

Figure 7-4 compares the capital spending in just Japan and North America. In 1984 and 1985, spending in Japan was significantly higher than in North America. However, in 1986 and 1987, capital spending in Japan was slightly less than capital spending in North America. In 1988, the Japanese market for capital equipment underwent a strong comeback and spending in Japan again exceeded that in North America. The capital spending forecast expects capital spending in Japan to continue to exceed capital spending in North America.

Capital spending as a percentage of production is shown in Figure 7-5. Capital spending as a percentage of production exceeded 30 percent in Japan in 1984 and in 1985, compared with 23 and 21 percent for capital spending in North America. However, in 1986 and 1987, the ratio of capital spending to production in Japan fell below the ratio of capital spending to production in North America. In 1988, the ratio of capital spending to production was greater in Japan than in North America. The forecast for this ratio is for it to continue to be higher in Japan than in North America.

Figure 7-3

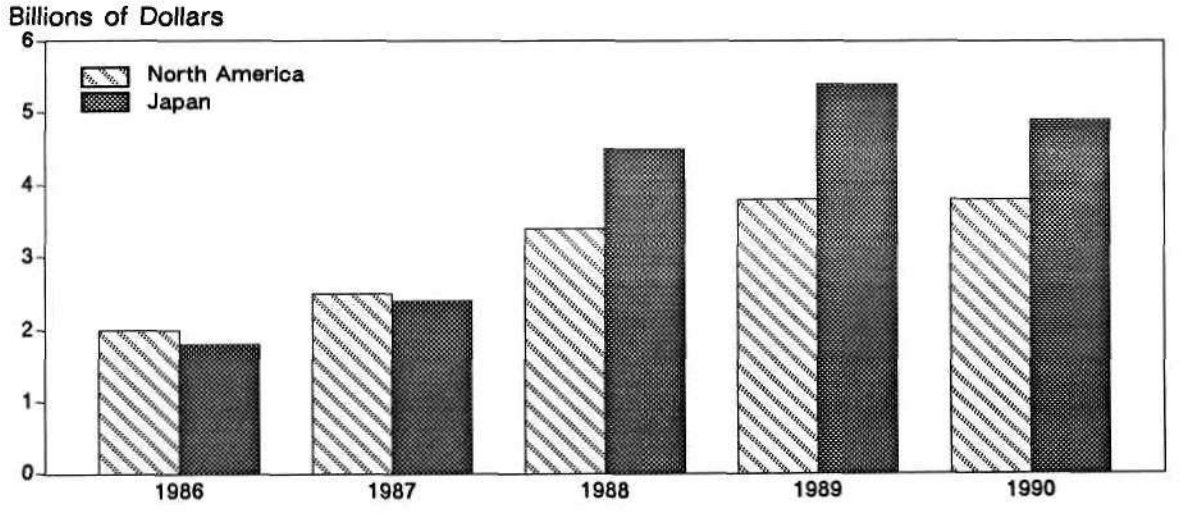
Worldwide Capital Spending by Region Regardless of Regional Company Base 1986-1988



Source: Dataquest September 1989

Figure 7-4

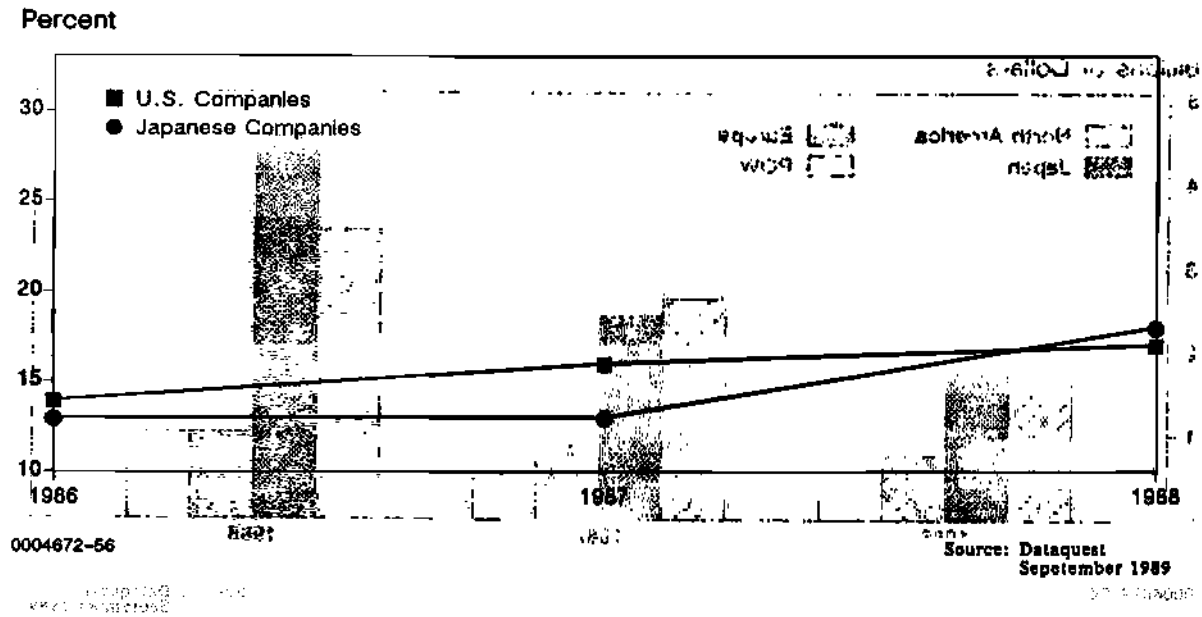
Estimated Semiconductor Capital Spending 1986-1990



Source: Dataquest September 1989

Figure 7-5

Semiconductor Capital Spending as a Percent of Semiconductor Sales



Semiconductor Equipment Demand Forecast 1989 to 1990

The equipment demand forecast by segment is shown in Table 7-4. The market reached an all-time high in 1988 with total sales of $4,895 million, which represented a growth of 58.0 percent over 1987. The market is expected to slow down, however, and 1989 sales are projected to be $5,576 million, for a growth of approximately 14.0 percent. We expect 1990 sales will be down at $5,422 million. The overall CAGR for the total equipment market is forecast to be 5.3 percent from 1988 to 1990. For the years 1991 to 1993, a return to annual growth in the range of 20.0 percent or more is expected.

The largest equipment segment is that of lithography, followed by deposition and etch and clean. Recently, deposition has been the most rapidly growing segment; it is expected to be so even during the predicted slowdown this year and next. Deposition is forecast to have a 6.3 percent CAGR from 1988 through 1990. Lithography is expected to have only a 0.5 percent CAGR during the same time frame because a very large number of steppers were installed in 1988 and will be installed in 1989. Thus, lithography capacity to fuel the next-generation devices has been or is about to be installed, and stepper sales in 1990 are expected to drop.

The capital spending and resulting equipment demand forecast by regional company base is shown in Table 7-5. Capital spending is forecast to grow at an annual rate of 23.3 percent in 1989 and to decline by 3.6 percent in 1990. Most of the predicted decline may be attributed to Japanese producers as their capacity utilization falls off somewhat due to the forecast decline in semiconductor production (see Chapter 6). Dataquest forecasts a healthy increase in demand for semiconductor equipment beyond 1990 as device production is forecast to expand vigorously in all regions.

The regional demand for equipment during the forecast period follows the semiconductor production and capital spending pattern forecast in Chapter 6 (see Table 7-5). We expect the Asian ROW and European regions to show the most capital spending growth with 1988 to 1990 CAGRs of 33.0 percent and 13.0 percent, respectively. Capital spending for U.S. and Japanese companies is much greater but is forecast to grow much more slowly (less than 6.0 percent) due to the forecast production slowdowns in these two regions. By 1990, Dataquest expects the combined equipment

consumption by Japanese and Asian ROW companies to rise slightly from a 55.6 percent share in 1988 to a 56.8 percent share in 1990. The forecast for capital spending by region of production, regardless of company origin, is shown in Figure 7-6.

Table 7-4

Worldwide Wafer Fab Equipment Forecast (Millions of Dollars)

	1988	1989	1990	CAGR 1988-1990
Lithography				
Contact/proximity	$ 21	$ 20	$ 20	(1.7%)
Projection aligners	159	140	140	(6.2%)
Steppers	903	975	900	(0.2%)
Direct-write e-beam	68	65	70	1.8%
Maskmaking e-beam/laser	59	70	80	16.1%
X-ray	9	10	20	49.1%
Total Lithography	$1,219	$1,280	$1,230	0.5%
Automatic Photoresist Processing Equipment	$ 250	$ 305	$ 275	4.9%
Etch and Clean				
Wet process	$ 235	$ 287	$ 275	8.2%
Dry strip	90	110	100	5.7%
Dry etch	547	610	600	4.7%
Ion milling	8	9	10	11.8%
Total Etch and Clean	$ 880	$1,016	$ 985	5.8%
Deposition				
Chemical vapor deposition	$ 455	$ 475	$ 450	(0.6%)
Physical vapor deposition	315	375	400	12.7%
Silicon epitaxy	85	85	90	3.2%
Metalorganic CVD	43	52	62	20.8%
Molecular beam epitaxy	85	100	108	12.5%
Total Deposition	$ 983	$1,087	$1,110	6.3%
Diffusion	$ 266	$ 330	$ 300	6.2%
Rapid Thermal Processing	$ 22	$ 25	$ 32	20.6%
Ion Implantation	$ 379	$ 450	$ 425	5.9%
CD/Wafer Inspection	$ 173	$ 250	$ 260	22.5%
Other Process Control	$ 427	$ 475	$ 450	2.7%
Factory Automation	$ 130	$ 168	$ 170	14.4%
Other Wafer Fab Equipment	$ 166	$ 190	$ 185	5.3%
Total Wafer Fab Equipment	$4,895	$5,576	$5,422	5.3%

Source: Dataquest
September 1989

Table 7-5

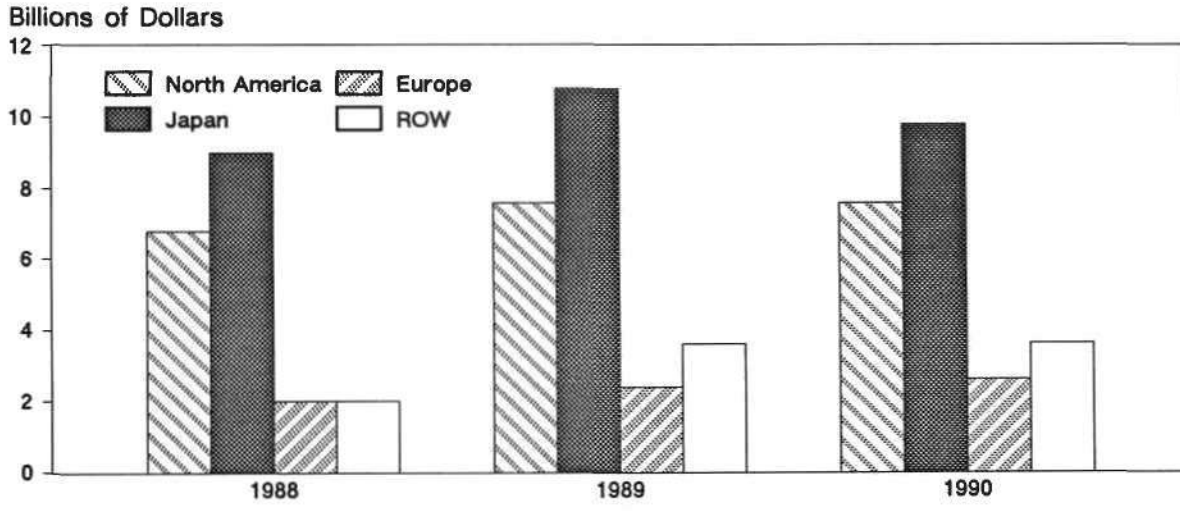
Regional Capital Spending and Equipment Demand Forecast
1988-1990
(Includes Captive Production)

	1988	1989	1990	Share 1988	Share 1990	CAGR 1988-1990
Worldwide Capital Spending						
U.S. Companies	3,434	3,826	3,839	34.2%	32.2%	5.7%
Japanese Companies	4,568	5,488	4,972	45.5	41.7	4.3%
European Companies	1,025	1,250	1,307	10.2	11.0	12.9%
ROW Companies	1,019	1,809	1,810	10.1	15.1	33.3%
Total Worldwide Spending	10,046	12,373	11,928	100.0%	100.0%	5.1%
Annual Growth Rate	56.1%	23.3%	(3.6%)			

Source: Dataquest
September 1989

Figure 7-6

Regional Worldwide Capital Spending Forecast
1988-1990
Regardless of Company Regional Base



0004672-57

Source: Dataquest
September 1989

In terms of dollars, the spending levels within Japan by Japanese and American producers will exceed spending level in North America by substantial margins. In 1989, our forecast calls for capital spending in Japan to be 143 percent of capital spending in North America. By 1992, spending in Japan will be 130 percent of capital spending in North America.

Strategic Issues Regarding the Equipment Demand Forecast

Impact of Regional Economy on the Forecast

The regional economic forecasts were provided in Chapter 3 and related to semiconductor production in Chapter 6. The fundamental economic impact on equipment demand is that which modulates semiconductor production and therefore demand for equipment that upgrades competitiveness or expands capacity. The relaxation of economic growth forecast worldwide, particularly in the United States, probably will moderate demand and production of semiconductors in 1990, especially in Japan, causing a predicted negative demand growth for equipment that year.

What Are the Demand Drivers for Semiconductor Production Equipment?

Analysis of new fab capacity from Dataquest's fab data base reveals that almost 90 percent of the new fab capacity in 1992 will be submicron.

The majority of equipment demand is forecast to be for upgrading manufacturing technology, which equates to fine-line geometries (sub-1.5-micron), particularly the 0.7- to 0.5-micron, 200mm wafer fab capability required for 1Mb DRAMs and beyond. Therefore, equipment segments that contribute to such fab capabilities will be in higher demand.

Regional Demand/Production Imbalances

The major suppliers of semiconductor production equipment are identified in Table 7-6. As discussed in the previous paragraphs, the regional base of these suppliers has shifted substantially over the period from 1979 to 1988. Japanese companies' share of the worldwide market in 1988 was approximately equal to that of U.S. suppliers for all wafer fab equipment.

However, the situation is worse for U.S. suppliers than it appears for two reasons. First, the Japanese are becoming increasingly dominant in their own market for equipment. Their share of the 1988 Japanese market for wafer fab equipment was 78 percent, up from 67 percent in 1982. Correspondingly, the U.S. share of the Japanese market in 1988 was 20 percent, down from more than 30 percent in 1982. Second, in the technically critical lithography segment of advanced stepper equipment, Japanese suppliers achieved 72 percent of the worldwide market while the U.S. suppliers obtained a 22 percent share. This is a technology that was innovated in the United States and at one point was wholly owned by U.S. companies. This also is a technology that is critical to submicron device geometries.

The concentration of market share among the top companies that supply the semiconductor equipment demand is shown in Table 7-7. The top 10 companies hold more than 54.0 percent of the market, and the top 20 control more than 72.0 percent. Furthermore, Table 7-8 illustrates the relative sizes of the wafer fab equipment suppliers. The top 12 companies (8.4 percent of all suppliers) are the only suppliers with revenue in excess of $100 million. The 87.0 percent of the companies, which total 123, have revenue below $50 million. In fact, less than 20.0 percent of the companies account for 80.0 percent of wafer fab equipment sales.

Table 7-6

1988 Top 10 Wafer Fab Equipment Suppliers (Millions of Dollars)

Rank	Company	Revenue
1	Nikon	486
2	Applied Materials	360
3	General Signal	248
4	Tokyo Electron, Ltd.	239
5	Canon	225
6	Varian	160
7	Eaton	147
8	Perkin-Elmer	141
9	Anelva	129
10	Hitachi	113

Source: Dataquest
September 1989

Table 7-7

Worldwide Revenue of Ranked Companies in Key Equipment Areas
(Millions of Dollars)

Companies by Rank	1988 Revenue ($M)	Percentage of Subtotal Fab Equipment
1-10	$2,248	54.3%
11-20	745	18.0
21-30	385	9.3
31-142	763	18.4
Total	$4,141	100.0%

Source: Dataquest
September 1989

Table 7-8

1988 Revenue Breakdown of Wafer Fab Equipment Companies
(Millions of Dollars)

	Number of Companies	Percent of Companies	Cumulative Percent
0 to $5	54	38.0%	38.0%
$5 to $10	28	19.7	57.7%
$10 to $25	31	21.8	79.5%
$25 to $50	10	7.0	86.5%
$50 to $100	7	4.9	91.4%
$100 to $200	7	4.9	96.3%
$200+	5	3.8	100.0%
	142	100.0%	

Note: Columns may not add to totals shown because of rounding

Source: Dataquest
September 1989

Many of these small companies are in niche markets and have opportunities for success and growth. However, the large companies have a firm lock on the bulk of the market. Three of the top five companies are Japanese.

Access to Capital

Table 7-9 illustrates the U.S. financial community's assessment of the value of companies within both the semiconductor manufacturing and semiconductor equipment and materials industries in terms of their 1989 estimated price/earnings ratios.

Concern exists that the ability for small companies to access sufficient investment capital through the U.S. financial community is so limited (see Table 7-9) that the most successful and strategically positioned companies become targets for acquisition by larger Japanese or European companies. Such acquisitions set up situations where innovative and creative entrepreneurs build a company around key new technologies only to stall out through failure of the financial community to respond appropriately to the strategic significance of the venture.

Table 7-9

Relative Valuations of Selected Technology Industry Groups

H&Q Industry Category	Calendar 1989 P/E Ratios*
Biotechnology	24 X
Medical Technology	18
System Software	17
Information Vendors	16
Instruments	14
CAD/CAM/CAE	11
Computer Systems	11
Infocomm	11
Semiconductor Components	10
Semiconductor Capital Equipment	9
Data Storage	7

*Calculated using closing prices on 9/21/88 and H&Q estimates for calendar 1989 earnings

Source: Hambrecht & Quist

This situation allows foreign investors with more strategic vision and more patient capital to "cherry pick" keystone technologies for themselves with little of the entrepreneurial risk. By this means, the independent, free-enterprise system of the United States could become a low-cost "breeding ground" for critical manufacturing technologies with which the Japanese maintain their superior competitiveness.

Continuation of these conditions all but guarantees further erosion of key new semiconductor manufacturing technologies to Japanese equipment suppliers, adding to the staggering regional imbalances that already exist. In the long term, such conditions gradually will eliminate the independent semiconductor producer within the United States. Except for a few specialty areas such as 32-bit microprocessors and the recent Sematech community DRAM effort where the United States has recognized the problem and protected its long-term interests, this loss of domestic semiconductor suppliers would, over time, eliminate the United States as the dominant force in computers, communications, and industrial electronic equipment.

CHAPTER 8

Executive Summary and Conclusions

This chapter presents a summary of the key points from the preceding chapters.

Overview

- In 1988, worldwide merchant semiconductor industry revenue totaled $50.5 billion. This represents a healthy 32 percent growth over 1987 and a doubling of annual revenue in just three years since the 1985 recession.
- The semiconductor industry is part of the electronics industry, the infrastructure, which is made up of a complex chain of buyers and sellers working together to satisfy worldwide demand for electronic products. This chain consists of several tiers beginning with the demand for electronic equipment, continuing to semiconductor devices, and ending with the demand for semiconductor equipment and materials. Demand for various products flows through the buyer/seller chain from one level to the next producing a cascading "waterfall of demand."
- Success of the $760.0 billion electronic equipment industry and the $50.5 billion semiconductor industry is dependent on the $18.0 billion semiconductor equipment industry.

Key Economic Points

- Electronic equipment represents 7 percent of the OECD members' output of goods and services. This amounts to $760 billion out of $10 trillion, measured in U.S. dollars.
- Of the three economic sectors—private business, government and consumer—demand for semiconductor devices is most influenced by private business. Within private business, semiconductor demand is influenced most by capital spending.
- Since 1987, the global economy has been expanding vigorously due primarily to capital spending by businesses.
- Worldwide economic growth is forecast to slow over the next two years.

Semiconductor Demand Summary

- The following three electronic equipment segments are the major contributors to semiconductor growth:
  - Data processing
  - Consumer equipment
  - Communications
- Major growth products have been personal computers, workstations, storage peripherals terminals, personal printers, VCRs, and compact disc players.
- As Japanese and Asian economies surge, they are consuming larger percentages of worldwide electronic equipment and in 1988, equaled Europe in size.
- Electronic equipment growth products have the following common attributes:
  - High semiconductor content
  - High unit volume
  - Large market (all of these products are utilized by individuals and thus are assured of a large total available market)
- Semiconductor demand is dependent on the following:
  - Equipment production growth worldwide
  - Semiconductor pervasiveness has grown from 6 percent in 1985 to approximately 7 percent in 1988. Semiconductor pervasiveness is measured as the dollar content of semiconductors as a percentage of the dollar value of the finished equipment.

- North America is still the dominant producer of data processing, communications, and industrial electronic products, but a clear trend has emerged that indicates significant erosion in market share for North American suppliers.

- Worldwide semiconductor demand is forecast to grow through the first half of 1989 and decline in the second half as the demand for electronic equipment declines. Worldwide merchant semiconductor demand growth for 1989 is forecast to be 15.2 percent and to have a 0.6 percent decline in 1990. The merchant market is expected to reach $58.2 billion in 1989 and decline to $57.9 billion in 1990.

Semiconductor Production Summary

- With more than 200 companies throughout the world producing semiconductor devices, the Japanese have four out of the top five companies. The top five semiconductor producers are NEC, Toshiba, Hitachi, TI, and Motorola.

- Japanese and Asia/Pacific countries have become the dominant forces in the semiconductor industry.

- The demand for semiconductors has shifted dramatically over the last four years as indicated in the following sentences:

  — In 1984, the Japanese and Asian ROW regions represented $11 billion or only 38 percent of the $29 billion total, while North America's share $13 billion, or 45 percent.

  — In 1984, North American demand for electronic equipment was 44 percent of worldwide equipment demand, while the Japanese and Asian ROW regions' share was only 21 percent. By 1988, the North American equipment demand fell to 40 percent, while the Japanese and Asian ROW share has climbed to 27 percent.

  — As the North American share of electronic production declined, the semiconductor demand market share fell from 45.0 percent in 1984 to 31.7 percent in 1988.

- Semiconductor product opportunities for the next few years are in the following areas:

  — ASICs

  — Specialty memories

  — Intelligent power systems

  — Microcomponents

- MOS memory revenue has become a significant factor in measuring the health of the industry. The price of DRAMs can inflate or deflate the overall industry sales volume, causing a distorted view of growth or decline.

- DRAM business is forecast to grow by 65 percent in 1989 and decline by 6 percent in 1990. This DRAM decline will contribute to a slowdown in the overall semiconductor industry in 1990.

- In 1988, MOS memory revenue composed 23 percent of the total merchant semiconductor revenue of $50.6 billion.

- Japanese and Korean producers have 75 percent of the merchant MOS memory market.

- MOS memory and microprocessors were the growth areas in 1988.

- The standalone semiconductor industry as it exists in the United States is threatened by the integrated industry as it exists in Japan. The critical question for U.S. merchant suppliers is: Can U.S. suppliers remain independent and survive?

- Another key question regarding the future of the U.S. semiconductor industry is: Can U.S. suppliers obtain the necessary funds to keep up with Japanese investments?

Semiconductor Equipment and Materials Summary

- We expect semiconductor equipment and materials demand in 1989 and 1990 to be driven by the need for new technology as fab lines come on line with line geometries less than 1.5 micron.

- Demand for semiconductor equipment is driven by the following:
  - Additional capacity—Producers need to expand capacity.
  - New technology—Producers need to increase competitiveness through new manufacturing technology.
- Manufacturing technology focus is on fab lines that have less than 1.5-micron geometries.
- By 1992, almost 60 percent of the square inches of silicon consumed will have line geometries of less than 1.5 micron.
- The key technology demand drivers for manufacturing equipment is in front-end (wafer fab) process related equipment that will do the following:
  - Produce fine-line geometries and provide more functions per die
  - Process larger wafers and yield more die per wafer
  - Minimize contamination and improve yields (track systems)
- X-ray lithography may well be the next critical technology in the pursuit of submicron geometries. The Japanese recognize this and are making significant investments.
- Capital spending within semiconductor producers is forecast to grow at an annual rate of 11.6 percent in 1989 and decline slightly in 1990, followed by a healthy demand beyond 1990 as device production expands in all regions. The bulk of the decline in 1989 is forecast to be from Japanese producers as their capacity utilization falls off.
- The top 10 companies (10 percent of all suppliers) are the only suppliers with revenue in excess of $100 million. Sixty companies have annual revenue below $50 million.
- Adequate capital is not available within the United States to fund new semiconductor equipment technologies. This leaves an opening for foreign investors to cherry-pick the best technologies. This will cause further elimination of U.S.-based independent suppliers and further weakening of the U.S. semiconductor industry.

United States—Summary Statements

- The U.S. electronics and semiconductor industry is facing a critical problem described as follows:
  - First, the U.S. market for semiconductors is shrinking as a percentage of the worldwide market due to the erosion of market share by U.S. electronics companies.
  - Second, Japanese and Asian semiconductor companies continue to gain share within the United States while U.S. semiconductor producers are not gaining share in Japan or other Asian countries.
- The three primary causes for the dramatic shift in the balance of economic power between the United States and Japan are shown as follows:
  - Many North American equipment producers moved offshore.
  - A shakeout of U.S. suppliers occurred.
  - The change in the exchange rate caused by the devaluation of the dollar beginning in 1986 caused an inflated view of the Japanese market share.
- The United States now is at risk of becoming a minor player in worldwide electronics market during the last decade of the century.
- Since nearly one-half of the world GNP is contributed by the United States, the continued health of the world economy depends on the health of the United States.
- The U.S. economy is projected to have slower growth beginning in late 1989 and lasting through 1990.