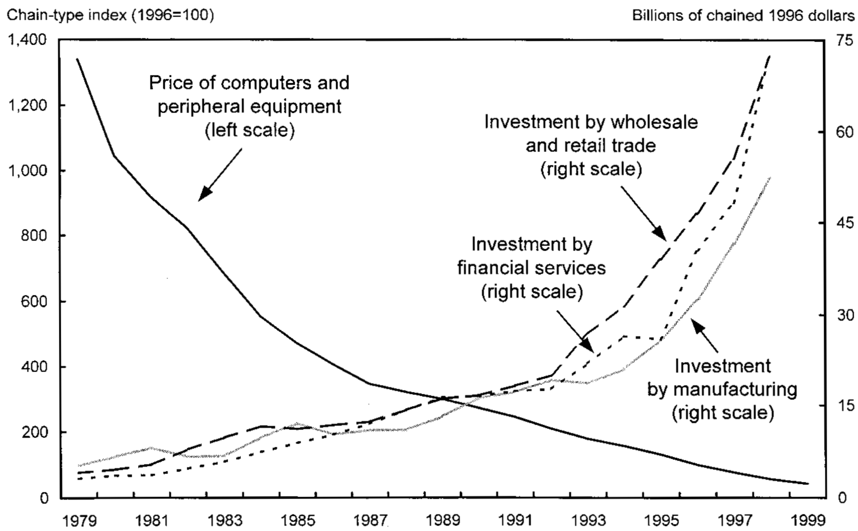
CHAPTER 3

The Creation and Diffusion of the New Economy

Computer Prices and Investment in Information Technology by Major Industries



Note: Information technology comprises computers and peripheral equipment, software, and communications equipment.
Sources: Department of Commerce (Bureau of Economic Analysis) and Department of Labor (Bureau of Labor Statistics).

Sharp decreases in computer prices have encouraged economy-wide investment in information technology.

At the heart of the New Economy lie the many dramatic technological innovations of the last several decades. Advances in computing, information storage, and communications have reduced firms' costs, created markets for new products and services, expanded existing markets, and intensified competition at home and abroad. These innovations have sprung from a remarkable recent flourishing of entrepreneurship, much of it concentrated in high-technology corridors such as California's Silicon Valley. Indeed, the rapid growth of the information technology sector was one of the most remarkable features of the 1990s. Domestic revenue in this sector—which comprises computer hardware, software, and communications—has grown by 120 percent over the last decade. In just the last few years, the Internet has spawned thousands of new companies and created billions of dollars in market value. Wireless telephone carriers alone now employ over 150,000 people in the United States and generate 10 times the annual revenue they posted a decade ago.

The information technology sector has been going about its highly innovative business since the 1970s. The last decade, however, saw a rapid convergence of several of its most important technologies—processing power, data storage and transmission, and software—that translated these innovations into real productivity gains. This chapter will show that these improvements in technology, along with intense competition and innovative organizational practices, have brought significant benefits to many industries throughout the economy. In manufacturing industries such as steel and automobiles, and in service industries such as retail trade and financial services, firms that have embraced information technology and developed custom applications are increasingly productive. Steel furnaces now use high-speed computers running what are called neural networks to improve quality and reduce wear and tear on equipment. In automobile production, networked computers are used for a whole range of activities from the design of new products to the coordination of supplier relationships. In financial services, advances in information technology have led to significant scale economies, reducing the costs of back-office operations, risk management, and customer support. Similar patterns of technological innovation are visible in many other industries.

Technology, however, is not the sole driver of this exceptional performance. During the 1990s, firms in many industries found that technology had its biggest impact when combined with complementary organizational innovations such as incentive pay, flexible work assignments, and increased training. Meanwhile intense competition, both at home and abroad, has forced firms to improve their performance—and weeded out those that do not.

This chapter surveys recent technological improvements, explores the causes of the recent surge in innovation, and explains how changes in technology, regulation, and competition have transformed organizations throughout the economy, leading to significant performance gains. The story is told in four parts.

The first part reviews recent improvements within the information technology sector, focusing on microprocessors, disk drives, and data transmission, and showing how costs have plummeted as capabilities have increased. Future advances in networking, wireless communications, and biotechnology—all fueled by the rapid technological advances of the last 20 years—will likely lead to even more impressive gains.

The second part examines the causes of the surge of innovation. Although the ultimate cause of all innovation is human creativity, the scope and complexity of technical innovation today require a particular support structure. Scientific and technical research and development (R&D) must be funded, researchers must be trained and equipped, inventors must receive adequate legal protection for their intellectual property, and so on. The discussion here focuses on the demand for technology, on financial market developments such as the growth in venture capital and a stronger market for initial public offerings (IPOs), on private and public R&D activity, and on intellectual property protection. None of these factors alone explains why the United States now finds itself awash in new technology. Rather, it is the convergence of these factors during the last decade that has created a unique climate for entrepreneurs to discover new technologies and bring them to market.

The chapter's third part explains how firms are producing goods and services more efficiently through greater use of computers and other information technologies and the development of complementary organizational practices. The emphasis is on how technology, regulation, and competition interact to create new business opportunities and spur performance gains. The financial services industry provides a useful illustration. As mentioned above, advances in information technology have led to significant scale economies in this industry. Deregulation now provides financial institutions the opportunity—and increased global competition provides the incentive—to exploit these scale economies. The combination of these factors helps explain the dramatic consolidation seen in this industry during the last few years. Further examples of changes in firm boundaries, internal organization, and performance are discussed, from the use of outsourcing and strategic interfirm alliances to new arrangements for compensation and job design. These changes in firm behavior, in many cases facilitated by the dramatic improvements in information technology, are immediate causes of the rapid productivity growth of the last 5 years.

The chapter turns finally to an investigation of the performance gains brought about by these new ways of doing business. There is considerable evidence that information technology and organizational change improve the performance of plants, firms, and industries. Globalization is also closely linked to improvements in firm performance: access to global markets gives firms strong incentives to improve their products and services, and the presence of foreign competitors in domestic markets forces firms to make those improvements or perish. As the competitive environment has changed, firms in many industries are increasingly turning to intangible capital—patents and trade secrets, organizational routines, reputation, and the like—as a source of competitive advantage. This has important implications for firm strategy, as firms seek new ways to build and exploit their stocks of these intangibles.

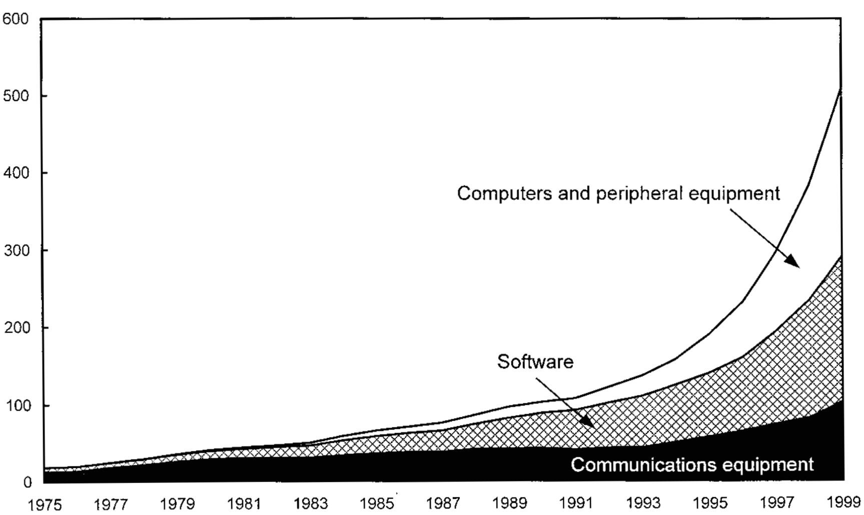
The Advance and Convergence of Information Technologies

The productivity improvements associated with the New Economy have their origins in a series of gradually unfolding advances in information technology that grew out of post–World War II defense research. Over the decades following these discoveries, the costs of processing, storing, and transmitting information fell dramatically. During the 1990s this process accelerated rapidly as computers became increasingly powerful, communications networks became much faster and cheaper, and firms developed the necessary software and organizational capabilities to translate these new technologies into performance gains. The emergence of the commercial Internet in the mid-1990s promises to extend these gains even further.

Clearly, the information technology sector has been one of the most innovative and visible in the New Economy. The sector now accounts for an estimated 8.3 percent of GDP, up from 5.8 percent in 1990. Private investment in information technology rose at a 19 percent annual rate over the 1990s as a whole and accelerated to 28 percent after 1995 (Chart 3-1). Advances within each area of information technology have created new markets, extended existing markets, and improved the efficiency of firms and industries.

Real investment in information technology rose at a 19 percent annual rate from 1990 to 1999 and at a 28 percent annual rate from 1995 to 1999.

Chart 3-1 Real Investment in Information Technology
Billions of chained 1996 dollars



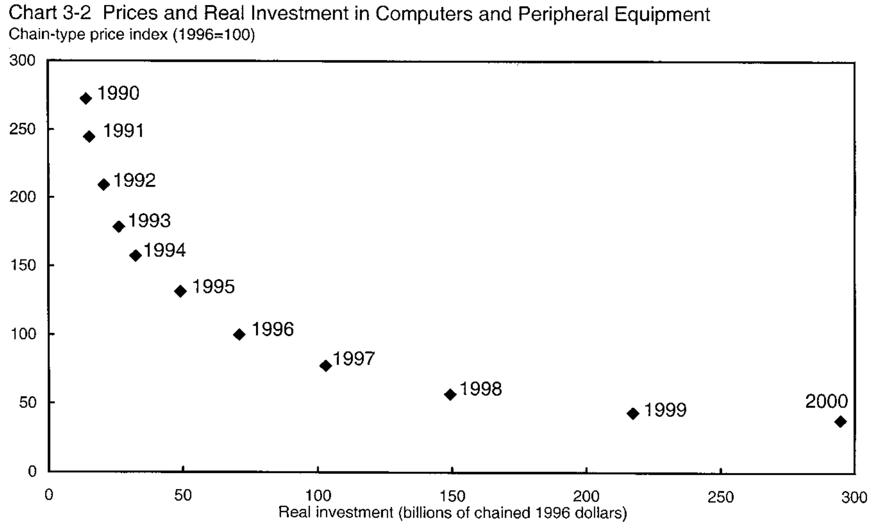
Source: Department of Commerce (Bureau of Economic Analysis).

The most impressive technological advances have come in terms of speed, storage capacity, data transmission capacity, and the improvement of user interfaces. Moore's law—the prediction by semiconductor pioneer Gordon Moore back in 1968 that transistor density on silicon wafers would continue to double every 18 months—has generally held true, generating one of the most remarkable phenomena of the late 20th century. Since 1980 the speed of microprocessors used in personal computers has increased more than a hundredfold, while the cost of performing 1 million instructions per second has fallen from over $100 to less than 20 cents. These advances, along with intense competition in computer assembly and distribution, drove quality-adjusted prices for computers and peripheral equipment down by 71 percent between 1995 and 2000. This coincided with a dramatic increase in private investment in computers and peripheral equipment (Chart 3-2). Complementary investment in software has nearly doubled. However, quality-adjusted prices of software have fallen by only 2 percent, reflecting in part the fact that labor is the major input into software production, and in part the difficulty of measuring quality improvements in this area (Chart 3-3).

Advances in data storage, which complement these advances in computer processing power, have also been impressive. The cost per megabyte of hard disk storage has fallen from over $100 in 1980 to less than 1 cent today. The newest generation of "microdrives," designed for handheld devices such as

As prices fell over the 1990s, real investment in computers and peripheral equipment increased dramatically.

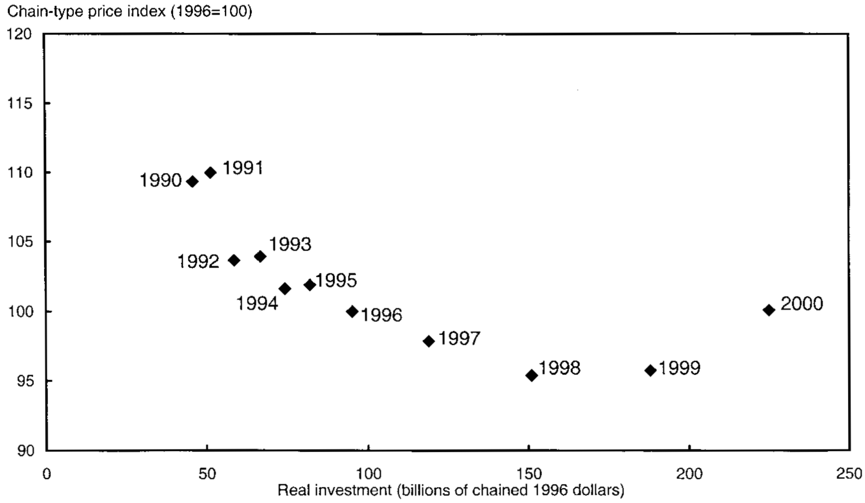
Chart 3-2 Prices and Real Investment in Computers and Peripheral Equipment



Note: The values for 2000 are averages of the first three quarters.
Source: Department of Commerce (Bureau of Economic Analysis).

As investment in computers soared after 1995, investment in software nearly tripled despite little reduction in prices.

Chart 3-3 Prices and Real Investment in Software



Note: The values for 2000 are averages of the first three quarters.
Source: Department of Commerce (Bureau of Economic Analysis).

wireless phones and digital music players, hold a gigabyte of data, are smaller than a matchbook, weigh less than an ounce, and sell for under $500. (By contrast, the first gigabyte-capacity disk drive, introduced in 1980, was the size of a refrigerator, weighed 550 pounds, and cost $40,000.)

Finally, data transmission capacity has skyrocketed: since 1996 the capacity of a single fiber-optic cable has increased by a factor of 20 in widely available commercial systems, and experts expect such technological progress to be sustained over at least the next 5 years. These improvements, again along with healthy competition, have reduced the cost of communications dramatically. Information can now be accessed from anywhere in the world via the public Internet at no cost once the user has connected. The emerging communications infrastructure allows firms to collect, store, process, and transmit information at ever-higher volume and lower cost. Between 1980 and 1999 the cost of sending 1 trillion bits of information electronically fell from $129,000 to 12 cents.

A revolution in software development has been built upon these advances in hardware. Private investment in software has risen from $11 billion in 1980 to $50 billion in 1990 and about $225 billion in 2000. The trend in software design is toward independent modules that can be combined for a variety of applications, and away from less flexible programs designed for individual users. Software has also become more sophisticated. Since about 1990, large firms have been spending billions on "enterprise resource management" programs: complex systems that integrate ordering, procurement, inventory, finance, and human resources. Smaller firms can get similar services from what are called applications service providers operating over the Internet.

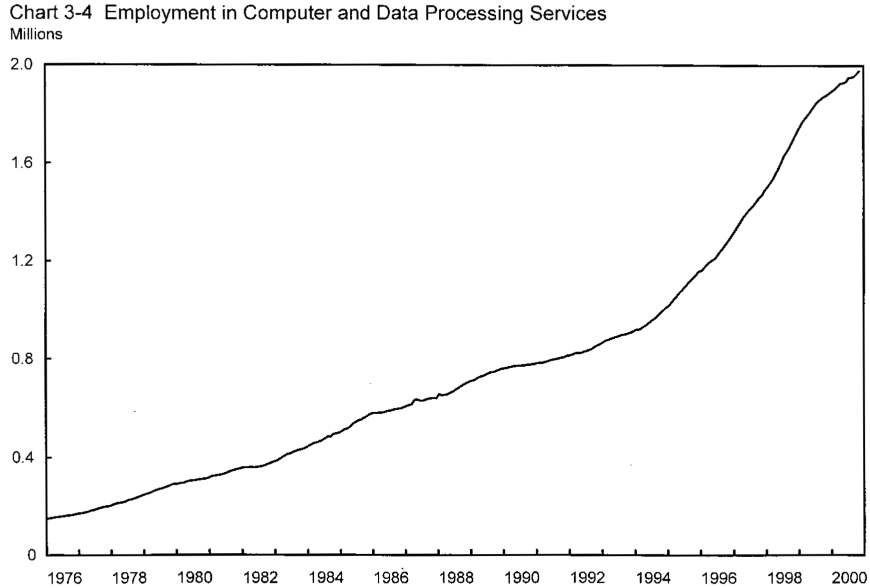
To reap the full benefit of these technological advances, firms are reorganizing many of their business practices. In some industries, firms are taking advantage of technological improvements by refining, expanding, and consolidating their operations so as to reduce costs; in others, startup companies are using technology to create new products, processes, and markets. Consumers are now being offered an increasing array of goods and services for wireless communication, digital entertainment, shopping, education, and other activities.

As firms have rushed to adopt this increasingly ubiquitous, lower cost technology and incorporate it into their businesses, employment in the computer and data processing services sector has exploded, more than doubling between January 1993 and November 2000 (Chart 3-4). This compares with only a 23 percent increase in total private U.S. employment during the same period.

Each on its own, these dramatic technological advances would have been unlikely to generate the profound transformations of firms and of consumer behavior that define the New Economy. Rather, it is the simultaneous convergence of these technologies that has made the difference. The rapid expansion of computer networks, culminating in the commercial Internet,

Employment in computer-related services doubled between 1994 and 2000.

Chart 3-4 Employment in Computer and Data Processing Services



Source: Department of Labor (Bureau of Labor Statistics).

clearly illustrates this convergence. Economists use the term "network effects" to describe how the benefits of participating in a network depend on how many other people are also on the network. (Who would want to be the only person in the world with a fax machine?) The number of Internet hosts, a proxy for the number of existing connections to the Internet, has increased exponentially since 1990 (Table 3-1). Nearly 42 percent of U.S. households have access to the Internet, and surveys indicate that over 50 percent of U.S. businesses sold products on line in 2000. The number of secure web servers for e-commerce in the United States rose from 7,513 in 1997 to 65,565 in 2000. Traditional firms and new firms alike are competing to deliver consumers higher speed access to the Internet and more sophisticated content and services for this new medium. Together this evidence suggests that the benefits of being on the Internet are growing at an extraordinary rate.

As the case of the Internet clearly shows, the most important breakthroughs of this information era have resulted from the convergence of fast processing, inexpensive data storage, and rapid communications. This technology is considerably more valuable to firms when combined with complementary human capital and the appropriate organizational routines, and when contractors outside the organization are available for development, implementation, and maintenance. The convergence of these technological advances, in combination with changing firm routines, has fueled much of the development of the New Economy.

TABLE 3-1.— *Content and Commerce on the Internet*

Year	Worldwide Internet hosts (thousands)	U.S. secure web servers for electronic commerce
1990	313	...
1991	535	...
1992	992	...
1993	1,776	...
1994	3,212	...
1995	6,642	...
1996	12,881	...
1997	19,540	7,513
1998	36,739	16,663
1999	56,218	33,792
2000	93,048	65,565

Note.—Internet hosts as of July of each year, except 1990 figure is for October. Secure web servers measured in September 1997, August 1998, August 1999, and July 2000, respectively.

Sources: Organization for Economic Cooperation and Development and Internet Software Consortium.

Why Is the U.S. Economy Awash in Technology?

What explains the recent surge of technical innovation? Of course, the ultimate cause of all innovation is human creativity. But technical innovation does not occur in a vacuum; it requires a structure of incentives and institutions. Firms demand new technology that will let them reduce costs and provide new products and services valued by their customers. For other firms to respond to that demand, scientific and technical R&D must be funded, researchers must be trained, their inventions must receive legal protection, and so on.

Government policies that foster competition, encourage R&D, and reduce trade barriers are important in this regard. The Administration has worked hard to provide an environment that allows entrepreneurship to flourish, particularly in the high-technology sector. For instance, the Administration supported a moratorium on U.S. Internet taxes under the Internet Tax Freedom Act and worked for a freeze on trade duties for electronically traded goods within the World Trade Organization (WTO). To encourage open markets in high-technology goods and services, the Administration signed the WTO's Information Technology Agreement, which will eventually eliminate tariffs on $600 billion worth of goods, and the WTO's Basic Telecommunications Agreement, which will promote competition and privatization in a global telecommunications services market worth $1 trillion.

To help ensure the competitiveness of U.S. firms in that market, the President signed the Telecommunications Act of 1996, the first comprehensive telecommunications reform legislation in over 60 years. In September 2000 the President signed an executive memorandum directing Federal agencies to work with the Federal Communications Commission and the private sector to identify the radio spectrum needed for third-generation wireless technology.

To encourage private sector R&D across the gamut of U.S. industries, the Administration worked to extend the Research and Experimentation tax credit through 2004, the longest extension of this policy ever. At the same time, the Administration has supported significant increases in funding for the National Science Foundation (NSF), an independent government agency responsible for promoting science and engineering. The NSF budget was increased by more than 13 percent in fiscal 2001, the largest increase ever. Overall, the President's 2001 budget request included more than $2 billion for R&D in information technology, a marked increase over the previous year's amount.

Within this favorable climate, technological innovation has proceeded at a rapid pace. This part of the chapter discusses the demand for technology, financial market developments such as the surge in venture capital and initial public offerings that support technology firms, the role of R&D expenditure in technological development, and the importance of legal protection for technical discoveries. It highlights four important features of the New Economy.

First, intense competition and feedback drive the development and adoption of new technologies. The availability of one technology stimulates demand for complementary technologies, which in turn lowers production costs and encourages further demand for the initial technology.

Second, significant financial market developments have lowered the cost of capital for new businesses. Although the public stock markets are still extremely important, providers of private equity such as venture capital firms are playing a larger role, particularly in the technology sector.

Third, the process of funding R&D has changed. The Federal Government continues to be a major provider of this funding. However, the emphasis of Federal funding has shifted from defense-related technologies to civilian products and services. More important, private R&D has soared, particularly at smaller firms and service firms. Private firms are also devoting an increasing fraction of their research budgets to basic, rather than applied, research. This suggests that the current technology boom is far from over.

Fourth, the innovative process has itself been transformed. Traditionally, innovation has been a highly integrated activity, performed mostly by large firms working independently of each other. Today, innovation is a less integrated process, performed increasingly by large and small firms in collaboration with each other, with academic institutions, and with government agencies. This is seen clearly in the computer hardware industry. Formerly dominated by large, vertically integrated firms, the industry is now frequently led by smaller, more specialized firms using modular technologies that are easily shared among market participants.

The combination of these features explains why the United States has seen so much technological innovation over the last decade. For the most part, these appear to be long-term trends, implying that technological progress will continue to be an important driver of U.S. economic performance.

The Demand for New Technology

Central to the dynamics of the demand for new technology is positive feedback: technological improvements generate increased demand for technology, which fuels further improvements. Several types of feedback are important here. First, in a market characterized by network effects, the more users have adopted a particular technology, the more valuable that technology will be for additional users. For example, the telephone, the fax machine, e-mail, and instant Internet messaging all are more valuable to any given user the larger the number of other users. Today, household telephone penetration in the United States is nearly 95 percent, more than 9 million fax machines are in use, over 100 million Americans have e-mail accounts, and more than 60 million use instant messaging software.

Second, for products that exhibit increasing returns to scale or strong learning effects in production, sufficient demand can generate larger markets by reducing the unit cost of production, which in a competitive market lowers price and drives demand even higher. Firms in the commercial aircraft and chemicals industries have long recognized the need to "price down the learning curve" to drive demand and maximize the returns on their investments. Semiconductor manufacturing, for example, is characterized by increasing returns to scale. Producing microprocessors or memory chips entails high fixed costs and low variable costs. The more the firm sells, the lower it can price its chips and still profit from its investment. As technological innovation brought ever-faster chips, the fixed costs of building a semiconductor manufacturing plant rose from $100 million in the early 1980s to $1.2 billion in the late 1990s. This suggests that increasing returns in the semiconductor industry are becoming increasingly important.

Finally, feedback can occur when strong complementarities between component products of a given system create an interdependent system of demand. For example, the demand for computers depends on the price and quality of software and of peripherals such as printers, modems, and scanners. Yet the demand for software and peripherals is, to a certain extent, determined by the price and quality of computers. More generally, since the complexity of so many information technology products makes it efficient to design each component for a particular purpose, and to establish standardized interfaces between components and even entire products, demand for individual components and given products becomes highly interdependent.

In the United States, deregulation, openness to foreign competition, and low administrative barriers to entry and exit have led to highly competitive markets, providing strong incentives for firms to adopt new technologies. Yet organizations often resist technological change. Adopting new technologies can be costly and risky for firms; some of this risk stems from the changes in relationships, communications practices, and organizational structures that are required to take full advantage of the new technology. A firm with a protected market position can avoid making these productivity-enhancing changes and still remain viable and profitable. Firms in competitive environments cannot. Beyond the highly competitive information technology manufacturing sector, which has been a remarkable user of new technology, competition has driven the demand for new technology in such service industries as telecommunications services, trucking, banking, and retailing, to name a few.

Financial Market Developments

Firms—especially small, innovative startup companies—need funds, guidance, and other forms of support for all aspects of their operations. The United States has offered a uniquely supportive climate for technology startups. In many cases a single individual investor, or "angel," has provided money at the seed stage, where a new firm's product concept is developed. Additional funds may be obtained through the private placement market—essentially equity offerings to a limited group. The Federal Government has also played a role in supporting innovation through the Small Business Innovation Research program. One of the most important factors in the financing of new technology, however, has been the recent acceleration in growth of venture capital, which itself has benefited from a thriving market for IPOs. The availability of venture capital has lowered the startup costs for aspiring entrepreneurs, and favorable taxation of capital gains has increased the demand of entrepreneurs for capital. Furthermore, a rising stock market may encourage venture capitalists to support startups, in the expectation that a subsequent public offering or private sale will generate large returns.

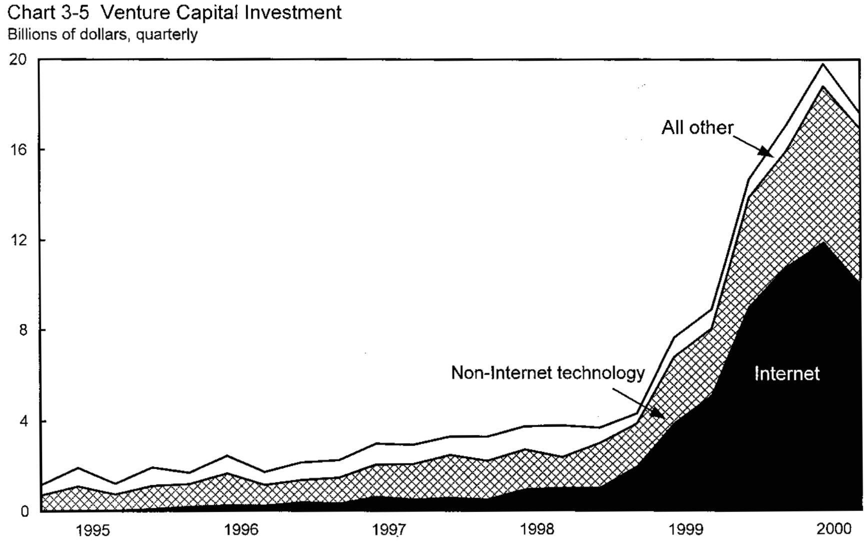
Venture Capital

Venture capital is a form of private equity that targets startup firms primarily in emerging industries. Venture capitalists do much more than supply funds, however. Besides matching entrepreneurs with investors, such as wealthy individuals, banks, and pension funds, they also advise, monitor, and support the projects they fund. Technology firms face two special obstacles in procuring finance. First, the profitability of the projects they pursue is extremely difficult to assess, and second, the entrepreneur's behavior is difficult for providers of capital to monitor and evaluate. Venture capital firms address these difficulties by getting deeply involved in the development of the typical startup. Typically, one or more of the venture capital firm's lead investors join the board of directors of the new firm, and from that vantage point they closely monitor the entrepreneur's activities. The method in which financing is provided allows additional control: the investment is typically staged, with funds disbursed only as the firm passes certain preset milestones. Venture capitalists often advise firms on the selection of key personnel and on the acquisition of legal and financial services. They are also deeply involved in the firm's strategic choices.

During the 1980s venture capital investment grew on average by 17 percent per year; then, during the 1990s, the pace doubled. Total venture capital investment jumped from $14.3 billion in all of 1998 to $54.5 billion in the first three quarters of 2000 alone (Chart 3-5). One company that tracks the venture capital industry estimates that $134.5 billion was under venture capital management at the end of 1999. Analysts pointed to the large

Technology companies, especially Internet-related firms, attracted huge amounts of venture capital in 1999-2000.

Chart 3-5 Venture Capital Investment



Note: Data for 2000 are through the third quarter.
Source: PricewaterhouseCoopers LLP, "Money Tree U.S. Report."

sums raised at the beginning of 1999, and to a new group of promising projects in Internet-related businesses, as the driving factors behind this surge in financing. Whether the rapid pace of growth can be maintained depends on a number of economic factors, one of which is the strength of the IPO market. Venture capital firms frequently move on to new projects once a firm has been successfully launched. For example, 3 years after an IPO, only 12 percent of lead venture capitalists retain 5 percent or more of the funded company's shares. And the most profitable manner for venture capital investors to exit their investment positions and take their profits is by having the new firm float a public issue. Therefore maintenance of a large and buoyant public equity market is critical.

The Federal Government has long been active in the venture capital business. Congress created the Small Business Investment Corporation (SBIC) program in 1958. This program allows the formation of SBICs, which are privately owned and managed investment firms, licensed by the Small Business Administration, that may borrow funds from the government in order to provide venture capital funding to entrepreneurs. In 1999 SBICs provided $3.7 billion to 3,700 companies.

Does the enormous growth in the amount of funds described as venture capital really signal a correspondingly large increase in the net resources available to entrepreneurs, or does some of it merely substitute for other sources of funding? There is evidence that not all venture capital is new money: some large firms, often in the computer hardware and software industries, now make about 15 percent of total venture capital investments through semi-autonomous organizations they set up. These investments might have been counted as internal corporate investment in the past. However, venture capital and traditional corporate R&D do seem to have different effects. In particular, recent evidence suggests that venture capital spurs innovation, as measured by patent activity.

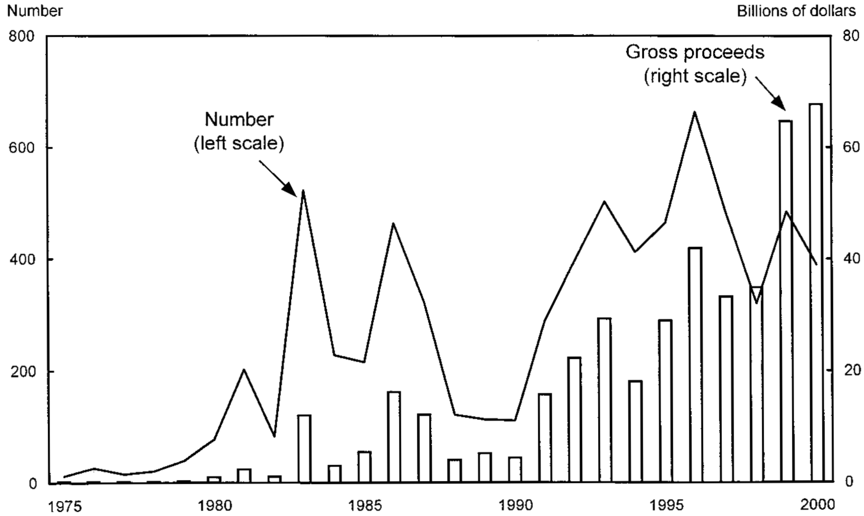
More generally, the thriving venture capital industry is but one part of a growing domestic private equity sector (as distinguished from the public capital markets, that is, the stock and bond markets). In the United States the private equity sector has largely divided itself into two subsectors, each focusing on different types of investments. One consists of the venture capital firms already described, which focus on early-stage investments in startup or newly formed entities. The other consists of investment groups that pursue opportunities in existing, more mature companies. At least 800 established buyout firms operated in the United States during the 1990s. These privately held firms specialize in leveraged acquisitions, recapitalizations, management buyouts, and other restructurings. In principle, buyout firms perform an important function by actively monitoring corporate managers, thus avoiding the collective action problems that limit effective control of management by institutional owners such as banks and pension funds. During the last five years or so, the distinction between venture capital and buyout firms has blurred: several buyout firms have begun investing in Internet startups, while venture capital firms that previously specialized in managing early-stage ventures have participated in buyouts of established technology firms.

Initial Public Offerings

In addition to venture capital, the public capital markets have also served as an extremely important source of capital during the second half of the 1990s and beyond. Between 1993 and the end of November 2000, IPOs raised $319 billion, more than twice the amount raised in the preceding 20 years, even after adjusting for inflation (Chart 3-6). Although some of the largest IPOs have been those of established firms seeking to raise additional capital, IPOs have also been an important source of capital for new firms, particularly in information technology and biotechnology. An active IPO market fosters innovation by providing capital for new enterprises and, as already mentioned, by providing an attractive exit mechanism for financiers of early-stage, risky ventures, making these financiers more willing to provide risky capital. It also provides liquidity for entrepreneurs, who can appropriate some of the value their efforts have created while retaining at least partial control of their firms.

The value of funds raised in initial public offerings has risen, and the number of offerings has been high.

Chart 3-6 Number and Gross Proceeds of Initial Public Offerings



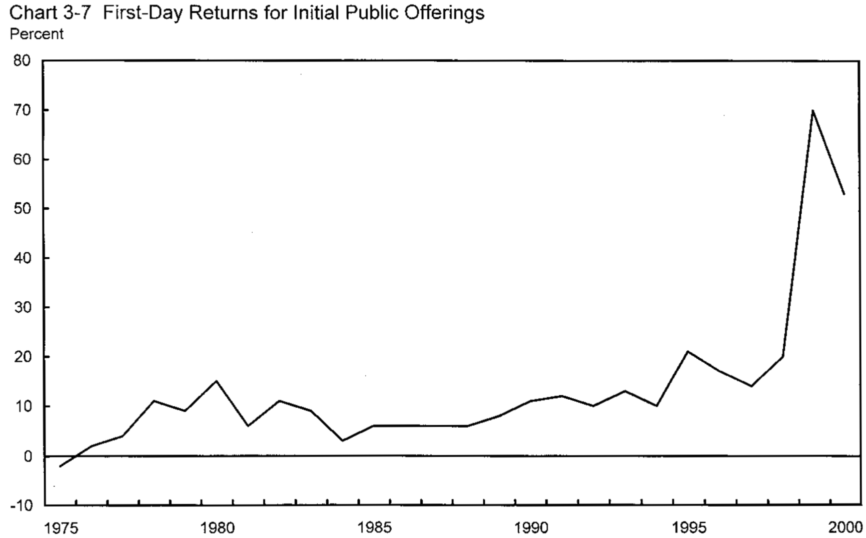
Note: The values for 2000 are based on data through November 30.
Sources: Jay Ritter, University of Florida, based on Securities Data Corporation data, and J.P. Morgan.

Of some concern, however, is the recent strange behavior of IPO pricing, especially in 1999 and 2000. In 1999 the average first-day return (calculated as the percentage by which the price at the end of the first day of trading exceeds the offering price) for IPO securities was an amazing 69 percent (Chart 3-7). This was three times higher than the average first-day return in any year between 1975 and 1999. This anomaly could be due to either "irrational exuberance" on the part of investors, persistent underpricing by the underwriters of these securities, or both. Economists have developed several possible explanations for the underpricing of IPO securities. Some focus on differences in the information held by the firm and the market, whereas others focus on the incentives of managers, underwriters, and investors. In general, underpricing is not necessarily the result of a market failure.

Evidence on the long-term performance of IPOs is mixed. Equity markets, particularly in the technology and Internet sectors, were extremely volatile in 2000. Internet commerce and Internet services firms recorded remarkably high market values between 1998 and early 2000, but their market values fell sharply after peaking in March 2000. Consequently, although the average number of IPOs per month in late 2000 was only slightly less than the average for the first half of 2000, the average monthly proceeds from IPOs fell by nearly 40 percent. The overall market value of equities remains high,

First-day returns for initial public offerings soared in 1999-2000.

Chart 3-7 First-Day Returns for Initial Public Offerings



Note: The first-day return is the percent by which the first-day closing price exceeds the offer price. The value for 2000 is based on data through November 30.

Sources: Jay Ritter, University of Florida, based on Securities Data Corporation data, and J.P. Morgan.

however. As of December 2000, the price-to-earnings ratio of S&P 500 firms stood at 26, substantially above its average of 22 in the 1990s. The price-to-earnings ratio of the Nasdaq composite stock index, which includes a high concentration of technology firms, was 98 near the end of 2000.

The availability of well-developed, sophisticated capital markets has provided important support for the technological advances of the last decade, although whether they will continue to do so in the next decade remains to be seen. The flourishing venture capital market and the dynamic IPO market are unique features of the U.S. economy and may help explain why the New Economy emerged here rather than in Europe or Asia.

R&D in the New Economy

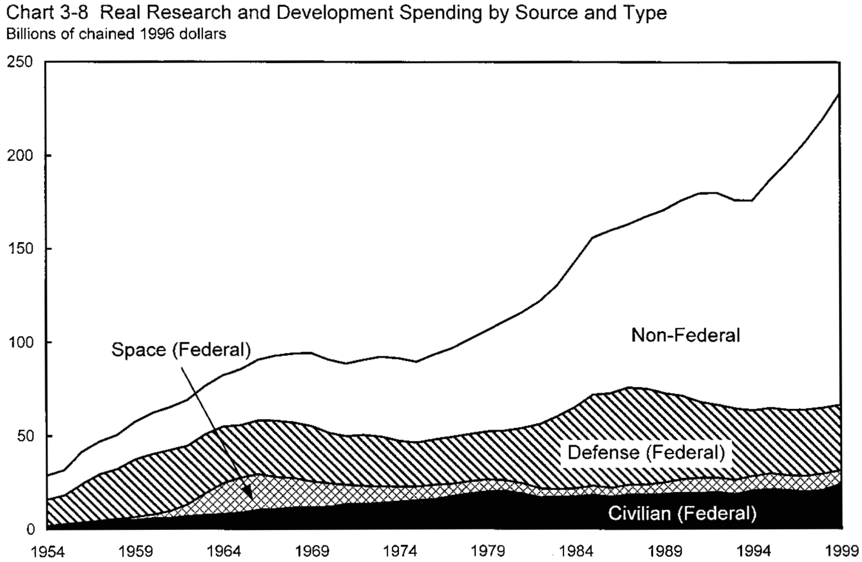
As the economy has become "lighter," shifting toward products that embody more knowledge capital and less physical capital, R&D—the principal means by which knowledge capital is created—has risen dramatically. The entire R&D process today is in the midst of a transformation away from the vertically integrated model pursued by large R&D laboratories and toward a more decentralized model involving more small-firm R&D and increasing collaboration between firms to bring products and services to market.

Between 1995 and 1999, real R&D spending in the United States grew at an annual rate of nearly 6 percent, evidence of a substantially increased commitment to innovation. Private sector R&D accounts for most of this growth, having increased at a remarkable 8 percent annual rate over the same period. In this era of budgetary restraint, real Federal support for R&D remained approximately constant but shifted somewhat away from defense R&D toward civilian applications (Chart 3-8). Other key indicators offer corroborating evidence of an increase in R&D activity. The number of scientists and engineers doing R&D rose 34 percent between 1995 and 1999. Immigration has been an important source of engineers and scientists in the United States, not only in R&D but in many other activities as well. Foreign-born persons make up only about 10 percent of the U.S. population, but about 13 percent of scientists and engineers.

Private sector support of basic research also increased rapidly in the 1990s, growing at an astounding 17 percent annual rate since 1995. Indeed, one survey observes that "industry is doing more long-range, high-risk, discovery-type research than ever before." This is somewhat surprising, because economists have typically argued that private firms will tend to focus on applied, rather than basic, research. Because basic research may not produce commercially exploitable results, and because firms fear that competitors will free-ride on their basic research investment if it does bear fruit, private firms are thought to invest little in basic research. In the early 1990s, in fact, several

Real Non-Federal spending on R&D increased sharply after 1993.

Chart 3-8 Real Research and Development Spending by Source and Type



Note: The values for 1999 are estimated.
Source: National Science Foundation.

large firms famous for supporting basic research scaled back their research budgets after experiencing sharp declines in earnings, raising concerns that private sector support for basic research would dwindle.

Why, then, did private sector support for basic research increase in the 1990s? A recent study shows that patent applications increasingly cite scientific research, and not just existing patents; this suggests that basic science is becoming more important for technological change. (This trend has been particularly strong in information technology and in biotechnology.) For this reason, firms that employ individuals skilled in performing basic R&D may be better able to take advantage of the scientific research performed by universities, the national laboratories, and other firms. Furthermore, as a recent study of postdoctoral biologists' job choices suggests, allowing researchers to pursue basic science and publish their results helps firms attract high-quality researchers and reduces the financial compensation that researchers demand.

The Organization of Innovation

Small firms have been responsible for much of the growth in private R&D. Between 1993 and 1998, real spending on R&D by firms with more than 25,000 employees increased by 8 percent, but R&D conducted by firms with fewer than 500 employees nearly doubled. In 1998 R&D conducted by firms with fewer than 500 employees accounted for 18 percent of all industrial R&D spending (Chart 3-9), and firms with 500 to 4,999 employees accounted for an additional 16 percent, compared with 12 and 14 percent, respectively, in 1993. More than 40 percent of all privately employed scientific researchers now work in these small firms.

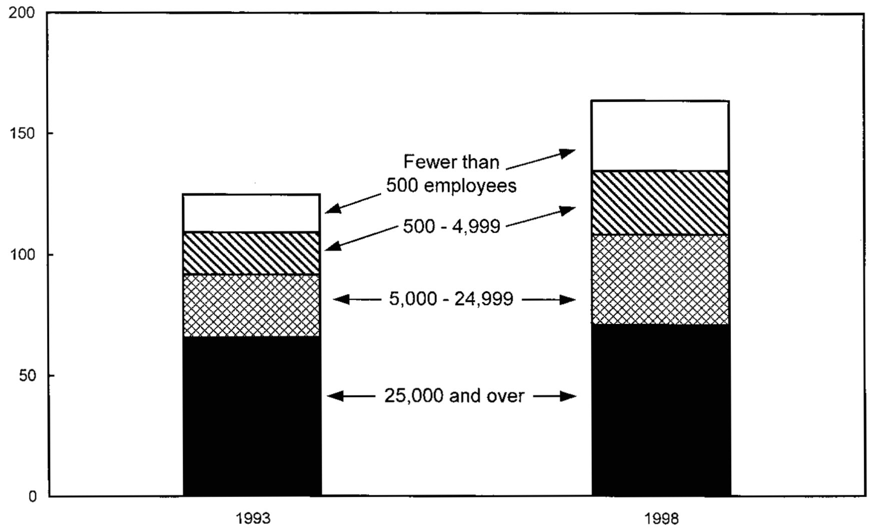
The increasing importance of small-firm R&D is consistent with an observed shift, in a number of industries, toward the distribution of innovative activity across multiple independent firms. For example, in the 1950s and 1960s, computer firms usually sold fully integrated, proprietary systems comprising both hardware and software. They developed and manufactured the majority of the components for these systems inside their own company. Today, in contrast, the most popular systems are based on modular architectures. Production of software and hardware is separated, and hardware manufacturing typically involves components designed and developed by dozens of different firms. Many of today's semiconductor design companies own no manufacturing facilities and focus exclusively on creating the intellectual property—the design itself. Still others perform contract production for dozens of these design companies.

Important changes have also occurred in pharmaceuticals. Before the 1970s the discovery of new drugs relied on what was called the random screening approach, which drew mainly on medicinal chemistry and pharmacology. Large, established pharmaceutical firms were the primary

Smaller firms conduct an increasing share of industrial R&D.

Chart 3-9 Total Expenditures on Industrial R&D by Firm Size

Billions of chained 1996 dollars



Source: National Science Foundation.

innovators. Today, in the wake of the molecular biology revolution, firms use a more profound understanding of the biological basis of disease to guide their search for drugs. Biotechnology has also become a technology for producing new drugs as well as discovering them, and the industry has seen the large-scale entry of firms that do both. In today's pharmaceutical industry, collaboration among major pharmaceutical firms, biotechnology firms, and academic institutions has become commonplace. The large drug companies have recognized that it is difficult to acquire all of the capabilities necessary to do modern pharmaceutical R&D; they must rely to some extent on external partners. The new biotechnology firms, for their part, have formed partnerships with the large drug companies that possess skills in conducting clinical trials and marketing that they themselves lack. Many biotechnology startups are closely linked to universities, and universities now routinely enter into licensing agreements with firms to commercialize the patents they hold.

In another departure from traditional R&D patterns, service firms also account for a considerable share of the recent growth of private R&D. The most recent data from the NSF show that service firms have stepped up their performance of R&D over the past few years. R&D by engineering and management services firms, for example, doubled between 1995 and 1998, to $8 billion, and in the same period R&D by business services firms increased by 69 percent, to $15 billion. Consistent with today's more decentralized approach to R&D, these service firms provide essential software for data processing and product development for their clients in manufacturing and other sectors of the economy.

Recent attention has focused on the management of innovation within and between firms. The design of incentives offered to researchers is important here. Incentive schemes must be carefully designed, particularly when multiple tasks—for instance, both basic and applied research—compete for a researcher's time and attention. Studies have suggested that firms seeking to develop promising but immature technologies with the potential to challenge their current business should establish separate, independent business units to develop these technologies. Otherwise the incentives of researchers and others within the organization could come in conflict.

Developments in information technology, meanwhile, have made possible entirely new R&D processes that further challenge the traditional centralized models. "Open-source" software design, which encourages users to modify the source code of a program and to share these improvements with others, has become increasingly widespread. Tens of thousands of programmers in the United States and abroad have contributed to open-source programs for such widely used products as Internet server software, e-mail routing software, and even some personal computer operating systems. Widespread Internet access has led to a dramatic acceleration in open-source activity, despite the fact that open-source programmers typically do this work without pay and distribute their source code for free. They may be motivated by reputation, which can lead to better future job offers and greater respect among peers, or by the sheer pleasure of solving the problem.

Another key feature of innovation and R&D in the New Economy is geographic concentration. Such concentration persists even in a world where declining telecommunications costs and improved software have made it easier for researchers in distant parts of the globe to collaborate. Knowledge spillovers between firms, and between firms and academic institutions, are particularly important in the technology sector. One study that looked at patent citations as a measure of these spillovers suggests that they are geographically localized; this finding remains even after controlling for preexisting research activity. Spillovers involving what economists call tacit knowledge—knowledge that is not easily codified or communicated except through close interaction—may be even more geographically localized, since they are likely to be mediated through social ties (for example, between an entrepreneur and a venture capitalist) or face-to-face contact. This creates geographic clusters of firms in a set of related industries. Many of the Nation's high-technology clusters benefit greatly from proximity to major research universities; besides Silicon Valley, examples include the Research Triangle in North Carolina, Route 128 in Massachusetts, and Austin, Texas.

Aside from the benefits from research spillovers, firms may choose to locate in these clusters to have better access to sophisticated customers, to benefit from the presence of supporting industries, and because startup costs—particularly the costs of hiring employees with a specific type of expertise—are lower. Clustering has been pronounced in industries where university R&D, private R&D, and skilled labor are particularly important.

Government Funding for R&D

The Federal Government continues to supply over half of all basic research funds in the United States, as it has since World War II (Box 3-1). Between 1993 and 1999, Federal funding for basic research increased at a 2 percent annual real rate. This funding increased a further 9 percent in fiscal 2000 and is budgeted to increase an additional 7 percent in fiscal 2001. Many New Economy technologies, such as the web browser and the Internet, have their origins in federally funded basic research. Other important technologies such as bar codes, fiber optics, and data compression also benefited from public funding in their early stages.

This Administration has increased basic research funding for many important technologies, computer science and biotechnology in particular. In 1999, 20 percent of the Federal research budget went toward health and human services research, and 50 percent of Federal basic research funds went toward the life sciences. Recently, Federal funding for basic research in information technology has increased. The Administration has established the Information Technology for the 21st Century Initiative, a basic research initiative targeted at software development, supercomputing, and networking infrastructure and examining the societal implications of the information technology revolution. This program had a budget of $309 million in fiscal 2000 and $704 million in fiscal 2001.

Any discussion of the Federal role in R&D requires careful consideration of whether public R&D complements or substitutes for private R&D. Some forms of R&D performed by the Federal Government are clearly complementary to private R&D spending. For example, providing information about the genetic basis of disease could increase the productivity of private R&D efforts to design new drugs. However, public R&D may at times crowd out private R&D if firms perceive that they can free-ride on government-supported projects, particularly those that focus on developing specific products. Time considerations may also be important. Today's Federal spending may support tomorrow's private spending but reduce the incentives for the private sector to do research today. Partly because of these considerations, the focus of Federal R&D spending has typically been on basic research, where underinvestment by private firms is thought to be most likely, and on R&D related to the missions of government agencies.

Encouraging Private Research and Collaboration

Besides providing direct funding, government policy has created a favorable climate for private R&D through the tax code and through encouraging collaboration among private sector firms. According to the Organization for Economic Cooperation and Development (OECD), the tax treatment of

Box 3-1. Federal R&D and Commercial Technology: Licensing, Cooperation, and Partnerships

A significant fraction of federally funded R&D supports the needs of Federal agencies pursuing public purposes such as national defense. However, the technology created by this research often has potentially valuable private sector applications as well. A series of new laws in the 1980s encouraged the realization of this potential by making technology transfer an explicit mission of the Federal laboratories. These laboratories were also given the authority to grant licenses on their patents to U.S. businesses and universities, and Federal agencies were allowed to enter into cooperative research and development agreements (CRADAs) with private firms to conduct research benefiting both the government and the CRADA partner. In the 1990s these technology transfer mechanisms took root and flowered in the Federal research enterprise. In 1998 Federal laboratories granted licenses for nearly twice as many inventions as in 1993, and nearly three times as many as in 1990. Not surprisingly, income from these licenses has risen dramatically. The number of active CRADA projects has doubled since 1993, with most such projects in the defense and energy spheres.

The missions of some Federal agencies target commercial applications specifically. The Advanced Technology Program (ATP), administered by the National Institute of Standards and Technology, supports research projects that focus on the long-term technology needs of U.S. industry, by sharing the cost of peer-approved, high-risk projects. Over 460 ATP awards—many of which have gone to cooperative ventures between firms and universities—have been made in fields as diverse as photonics, manufacturing, materials science, information technology, and biotechnology.

Founded in 1993, the Partnership for a New Generation of Vehicles (PNGV) is another example of how Federal agencies and industry have joined forces to pursue mutual interests. The PNGV brings together the three major U.S. automakers, over 300 automotive suppliers and universities, and seven Federal agencies to develop technology for environmentally friendly vehicles. The vehicles developed under this program promise to achieve up to triple the fuel efficiency of today's vehicles, and very low emissions, without sacrificing affordability, performance, or safety.

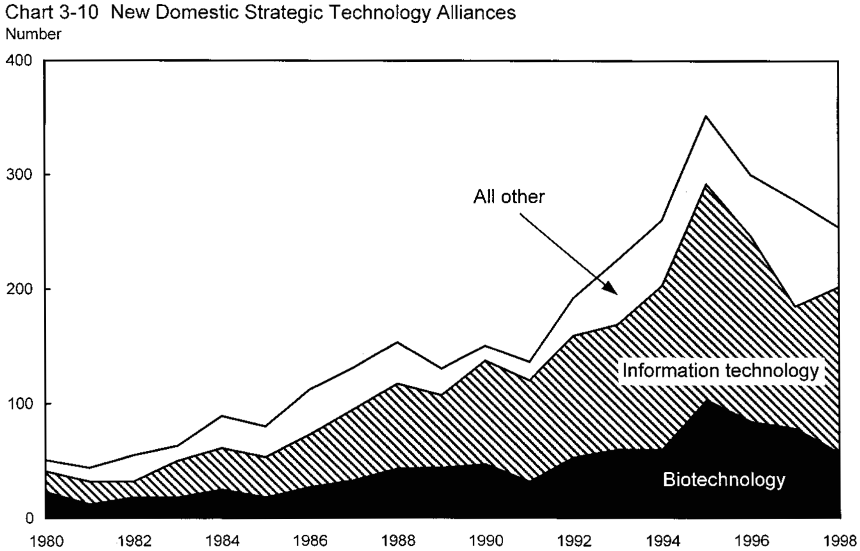
R&D in the United States is one of the more favorable among OECD nations. Federal policy has also encouraged the formation of strategic technology alliances, which are particularly important for new modes of R&D. Two hundred and fifty-five domestic U.S. technology alliances were formed in 1998, up from a mere 51 in 1980 (Chart 3-10). The number of alliances formed between U.S. and foreign firms climbed from 88 in 1980 to 222 in 1998. This growth in new alliances was driven largely by agreements between firms in information technology and biotechnology.

One particularly intensive type of technology alliance is the research joint venture. Research joint ventures allow participating firms to take advantage of their different and often complementary capabilities, to spread the risk of a project, and to pool resources. For example, two major firms working on computer memory technology recently announced a joint effort to develop magnetic random access memory (MRAM). This technology promises more efficient computing—machines using MRAM will start up instantly, for example. One company has created the early MRAM technology itself, whereas the other brings to the venture additional expertise in complex semiconductor memory. Combining the efforts of some 80 engineers, the firms hope to develop commercially viable MRAM by 2004.

Research joint ventures limit wasteful duplication and are particularly important for projects whose payoffs are likely to be years away. Most important, they allow firms to internalize some of the benefits of knowledge

Increased activity in high-technology industries led to a rise in the number of new domestic strategic technology alliances in the 1990s.

Chart 3-10 New Domestic Strategic Technology Alliances



Source: National Science Foundation.

spillovers; the difficulty in capturing these externalities is presumably a reason why firms are thought to underinvest in R&D in the first place.

Although technology alliances existed before the mid-1980s, U.S. antitrust law created some confusion about the extent to which firms could cooperate on R&D. With passage of the National Cooperative Research Act in 1984, the treatment of research joint ventures under antitrust law was modified in two important respects: the application of antitrust law to such ventures was clarified, and the maximum penalty that could be assessed in a successful private lawsuit was reduced. The 1993 National Cooperative Research and Production Act further liberalized the environment for cooperation by extending these provisions to include the application of technologies developed by joint efforts. Seven hundred and forty-one research joint ventures were registered under this act through 1998, with most occurring in the communications, electronics, and transportation equipment industries.

Intellectual Property Protection

Perhaps the chief incentive for innovation is the potential financial reward from owning a unique resource, product, or service. Innovators often profit simply by being first to market, but legal protection for their discoveries provides an additional attraction. U.S. law provides particularly strong intellectual property protection. For example, it allows the patenting of most biological material that occurs as a result of substantial human intervention, and this protection has contributed to the rapid innovation in the U.S. biotechnology industry. European case law for biotechnology patents is evolving but inconsistent, and the European Union does not currently grant patents for plant varieties. Japanese law for the patenting of living material is similar to that in the United States, but Japan prohibits the protection of biotechnology inventions related to the human body for the purpose of diagnosis or treatment of disease.

In addition, the United States grants clear protection to a variety of computer-related innovations, an area that Japanese and European laws protect more loosely. The European Patent Convention specifically notes that computer programs as such are not to be regarded as inventions. Although court rulings have interpreted this as requiring that software inventions make a technical contribution to be eligible for a patent, considerable misunderstanding remains in the European Union about the extent of patent protection for software, particularly among small and medium-size enterprises. In Japan a software patent claim can only be expressed as a claim on the process, whereas in the United States claims can cover a product or a process. This means that, in Japan, many more patents may be required to fully cover a new software package; this increases the possibility of a gap in protection that a competitor can exploit. In both the European Union and

Japan, a software patent is substantially narrower than one granted in the United States.

As more new technologies emerge, challenges to incorporating these innovations into the intellectual property framework will continue to surface. As it did with earlier innovations, the existing intellectual property framework is adapting to accommodate today's new technologies. For instance, the increasing use of software has blurred the line between a physical transformation, which is traditionally covered by the patent system, and a concept, which is not. Court rulings have consistently upheld the patent protection of "business methods"—financial techniques or software programs that suffuse technology and concept. However, the legal rulings in favor of business methods patents have generated controversy, as illustrated by the debate surrounding a large Internet retailer's patenting of its website ordering process. Critics argue that patents of business methods are of low quality and overly broad, and that they might stifle innovation. In response, the Patent and Trademark Office announced the Business Methods Patent Initiative in early 2000. The initiative establishes new procedures for reviewing such patents, including a second layer of patent review, enhanced training for examiners, and expanded searches for prior work.

The proliferation of new technologies has also raised issues related to copyright and trademark law. "Peer-to-peer" file-sharing systems permit the easy exchange of copyrighted media, including music, software, video, and texts. The Administration has supported the extension of copyright protection to the digital realm and has worked to establish an international standard of copyright. One achievement in this area was the passage of the Digital Millennium Copyright Act (DMCA), which implements the Copyright Treaty and the Performances and Phonograms Treaty of the World Intellectual Property Organization. Among other provisions, the DMCA limits the extent to which Internet service providers can be held accountable for copyright infringement by their users.

As biotechnology, the Internet, and other innovative technologies become more widespread, important legal challenges will continue to emerge. For example, e-signature legislation recently took effect, providing standards under which legally binding signatures can be created and sent electronically. This advance brings with it important new challenges in contracting.

A Favorable Alignment

Why, then, is the U.S. economy awash in technology? The evidence suggests that the combination of increased, competition-driven demand for technology, thriving financial markets, increased public and private R&D, and legal protection have created a uniquely favorable climate for entrepreneurship in the technology sector. As this chapter has emphasized, it is not any one of these factors in isolation but rather the convergence of these favorable conditions that has led to the recent surge in technological innovation. Technology flourishes when markets are allowed to work, and where government policy provides essential support.

Doing Business in the New Economy

How has growth in technological innovation affected the economy as a whole? Chapters 1 and 2 of this *Report* detailed the effects of information technology on economy-wide productivity. Here the focus is on the effects of technology, along with complementary organizational practices and increased global competition, on the behavior of individual plants, firms, and industries. The remarkable productivity of the information technology sector itself over the last several decades has already been discussed. This part of the chapter turns to other sectors of the economy, to show how the technologies and business methods of the New Economy have spread beyond the information technology sector.

Chapter 1 presented aggregate evidence that the New Economy has diffused outside the information technology sector to the service-producing industries. Between 1989 and 1999, labor productivity accelerated in retail and wholesale trade and in finance and business services (Table 1-2). These industries are heavy users of information technology, and this technology may have contributed to these gains. However, the aggregate statistics do not provide the whole picture. Productivity gains in these industries are difficult to gauge: measuring output and prices is an imperfect exercise, and the productivity numbers do not incorporate important changes in quality. To understand and extend these findings, then, it is essential to look at evidence within firms and industries. This section focuses on the underlying mechanisms by which performance gains might arise.

These performance gains come mainly from two sources. First, the level of investment in information technology has increased sharply, in both the manufacturing and the services sectors. As discussed in Chapters 1 and 2, only since 1995 has investment in information technology grown to the point where the stock of information technology capital can itself have a noticeable effect on aggregate productivity. However, computers are more than just another factor of production. As this section will emphasize, another important driver of productivity growth is the way computers and electronic communications together enhance the efficiency of labor and other factors, as firms adapt these technologies to their own unique business applications. It is these increases in the productivity of all factors that explain the economy-wide gains documented in Chapters 1 and 2.

Information technology has made inputs more productive by changing the way firms do business. In manufacturing, increasing computing power and decreasing cost have brought about performance gains through automation, numeric control, computer-aided design, and other channels. Information technology has also facilitated changes in job design, giving manufacturing workers more decisionmaking authority on the shop floor and placing a premium on technical skills. Firms are also relying increasingly on performance-based pay, including profit-sharing and stock option plans.

Supplier and customer relations have also changed. Supplier contacts that were formerly kept at arm's length have become more closely integrated and coordinated, thanks in part to automated procurement systems. Data that used to be kept proprietary are now increasingly shared between business partners. Inventories have shrunk. Firms use databases of transaction histories to target products and services to individual customers, while setting up telephone call centers and other operations to improve service.

The structure of many markets has changed. In some sectors high fixed costs and low marginal costs, combined with first-mover advantages and network effects, have led to highly concentrated markets. Other sectors are populated by smaller, newer firms. Firm boundaries are also shifting more rapidly as firms move toward flexible, collaborative relationships such as strategic alliances with suppliers and even potential rivals.

Finally, competition in the New Economy is more vibrant, more dynamic than ever before. Many markets have become more "entrepreneurial" as new business starts—and business failures—have increased. The increase in global trade brought about by trade liberalization along with lower communications and transportation costs has led to improved performance. This section outlines the effect of technology, organization, and other factors on performance.

New Developments Inside Plants and Firms

Many people associate the New Economy with semiconductor plants or biotechnology research laboratories. Those are, of course, important drivers of recent performance improvements. However, information technology has had significant effects on old-economy industries as well.

Applying Computing Power Outside the Information Technology Sector

As computing power has gotten cheaper and firms have made greater investments in information technology, they have learned to apply that greater power to improving the performance of the firm. Manufacturing firms have done this by investing in information technology that is embedded in much of the new machinery they install, and by investing in information technology in their business processes. Service firms have used the new technologies to introduce new products and processes as well. Although the case studies presented below do not add up to an economy-wide measure of the impact of information technology, they do show clearly that it is improving productivity in many sectors of the economy—even old-economy industries such as steel, transportation, and banking.

In the manufacturing sector, computers allow the automation of many tasks, improving the flexibility, speed, and reliability of the production process. The machine tool industry provides an example (Box 3-2). These improvements in the production process are also combined with the use of new software that governs scheduling mechanisms, to reduce work in process and shorten lead times for order fulfillment. In the services sector, the availability of information and the increased ability to process that information have enabled retailers and service providers to respond more quickly to changing customer demand and to provide more customized service.

The changes witnessed in the steel industry exemplify these changes in production processes and management practices. The fundamental processes of steelmaking remain much as they always were: melting raw material, forming it into an intermediate product, and shaping and treating that product into final goods. But a number of technological advances, many incorporating information technology to measure, monitor, and control these processes, have affected almost every step in steel production.

As recently as 10 or 15 years ago, steelmaking involved extensive manual control and setup and relied heavily on operators' experience, observation, and intuition in determining how to control the process. Computer processing of data from sensors, using innovative software, has improved the ability to control the process, allowing faster, more efficient operation, in addition to more uniform product quality. For example, the availability of computing power to quickly process data has enabled steelmakers to combine sophisticated software decisionmaking algorithms (called neural networks) with precision sensing devices to continuously monitor and adjust the ever-changing conditions in the electric arc furnaces widely used for melting steel. This closer control reduces both energy consumption and wear and tear on the equipment. The setup to cast the molten steel into an intermediate product has changed from a process in which several operators would "walk the line," setting the controls for every motor and pump, to one in which a single operator uses an automatic control system that synchronizes and sets the equipment. The rolling process now incorporates sensors that constantly inspect for deviations from the desired shape, allowing the operators to make corrections before material is wasted. Operators can remotely control the speed and clearance of the rolls using computer-controlled motors to correct problems as they develop.

Box 3-2. Information Technology in the Machine Tool Industry: The New Economy Helps the Old

The machine tool industry, one of the oldest and most basic of U.S. manufacturing industries, appears to have experienced accelerated performance in the 1990s as a result of improvements based on information technology. Because this industry makes the machines used in the rest of the manufacturing sector, improvements in the quality of its products can result in productivity gains for the entire sector. The annual productivity growth rate for this industry rose to 2.5 percent from 1990 through 1998 after more than a decade of decline. But even this figure underestimates the performance gains that have arisen from improvements in such factors as reduced inventories and higher product quality.

The use of computerized, numerically controlled machines in this industry has had a major impact. Although developed in the 1970s, numerically controlled machines made up only 5 percent of the machining base by 1983. By 1997, however, this share had risen to 68 percent. These machines increase operating speed: one study found that as of 1987 they had already reduced unit production time by 40 percent relative to manual production. They also increase output quality and reduce setup times, so that products can be switched more frequently and inventories can be kept smaller.

One industry that uses these production methods is valve production: valves are seen in virtually every industrial environment, where they are used in pipelines to control the flow of liquids or gases of various kinds. Data described below from a typical valve-making firm document pronounced productivity gains in three primary areas of the firm: new product design, production, and inspection. To envision these phases, imagine that the firm is making a complicated valve part starting with a chunk of steel, then boring a hole in the middle for liquid flow, turning grooves on the end, and finally drilling and tapping additional holes and turning protrusions that permit control devices to be attached.

New Product Design

New product design is a primary element of production, because valve production is often very specialized; small numbers of valves must be produced that are unique to the new application for which they are ordered. In the 1990s the computer-aided design software used by valve-producing firms became capable of displaying three-dimensional images, showing the valve as a solid model rather than as a flat planar representation. This change speeded design time enormously. The new software also allows all the properties of the valve,

continued on next page...

Box 3-2.—*continued*

such as stress loads and the center of gravity, to be calculated automatically, thus eliminating the need for extensive manual calculations. It also eliminates the need for a demonstration model and significantly improves design quality. One firm estimates that the new software has reduced design time by more than 50 percent and cut the required number of engineers and draftsmen on a typical job by 30 percent. Thus, although at least 84 percent of all manufacturers had introduced computer-aided design in some form by 1997, the very recent move to three-dimensional design is likely to have a particularly strong impact on performance.

New Production Methods

Numerically controlled machines were introduced 25 years ago, but the recently developed computer numerical control (CNC) machines can produce valve parts much more rapidly. These machines are run by sophisticated software with a simple graphical user interface that enables the operator to produce a typical complicated part in one day, compared with the four days it would have taken previously. Moreover, the CNC machine is much more versatile. Two CNC machines are enough to produce a new valve that might have required eight of the earlier-generation machines 10 years ago.

New Inspection Techniques

A complicated valve often must be machined in each dimension to a tolerance of 1/1000th of an inch. Therefore inspection is a critical part of the production process. For many years inspection was done with manual measuring devices, which was very time consuming. Inspection machines developed in the last few years instead use a probe technology, so that the operator simply touches each surface of the valve with a probe, which then generates a three-dimensional image and measures all dimensions. The new device can cut inspection time for a typical complicated valve part from 20 hours to 4.

The Importance of Information Technology

The machines that make today's complicated valves are run by sophisticated software programs that require high-speed computing and extensive data storage. These new machines are now available and affordable because the costs of computing have plummeted, and because capital goods makers have had time to learn how to harness cheap computing power by developing the applied software needed to run the machines. Thus the performance improvement in valve production has come about partly as a result of high levels of new investment, but also because the information technology imbedded in all new machinery enables these machines to perform at rates previously unachievable.

The result of this integration of computers into steelmaking has been a significant improvement in performance. Together with other technological changes, such as larger furnaces and improvements in casting practices, and the closing of older, inefficient plants, the new technologies have also contributed to higher product quality and productivity. Steelmakers today use less than 4 worker-hours to produce a ton of steel, down from about 6 worker-hours in 1990. The best-performing mills have achieved results of less than 1 worker-hour per ton.

Service industries, too, have harnessed information technology to change the way they do business. The trucking industry is using the new technology to better serve its customers' logistics needs. To be efficient, trucking firms must satisfy customers with prompt pickup and delivery of loads while minimizing unused capacity in the form of both idle equipment and empty and incompletely loaded trips. By coordinating information from many shippers and consignees in a geographical area, firms can reduce wasted movement. To track and dispatch trucks efficiently, they use sophisticated locating technology, such as the satellite-based global positioning system; real-time traffic, weather, and road construction information; computers on board the trucks themselves; complex software and algorithms; and supporting hardware to organize customers and loads. The ability to effectively use information to manage shipments not only contributes to efficiency but also enables other innovative processes such as automated exchange of information.

Banks have also used new technologies to improve their processes. In the mid-1990s retail banks introduced imaging technology to process checks more efficiently. Digital images of checks are stored on a central computer and scanned by software that reads the amounts on the images. Checks are then balanced against deposit slips automatically. Introducing this technology has freed employees from having to record check amounts manually, lowered transactions costs by eliminating the need to move checks physically, and allowed banks to reorganize their workflow around a more extensive division of labor.

Complementary Changes in Organizational Practices

To fully realize the performance gains from the applied use of information technology, firms often must make complementary changes in organizational practices. For example, the information that the new technology puts in the hands of production line operators is valuable only if those operators have the authority to use it to make decisions about the operation of the line. The move to place greater decisionmaking authority in the hands of line personnel is one key example of an organizational change that complements the adoption of information technology and enhances its value. Another complementary change is in the incentives that operators and other employees have to use information to make better decisions.

There is evidence that in the last 10 years more firms have placed greater decisionmaking authority in the hands of the average employee. The growth of processes to increase employee involvement and the delegation of decisionmaking to the shop floor, for example through off-line problem-solving teams or self-directed work teams, indicate how line employees are performing functions that used to be retained as management prerogatives. A survey of manufacturing establishments found that the share of establishments adopting at least one employee involvement practice (defined as quality circles, job rotation, teams, or total quality management) rose from 65 percent in 1992 to 85 percent in 1997. The share of establishments reporting the use of multiple employee involvement practices rose from 37 percent to 71 percent over the same period. As employees take on more responsibility and are involved in more complex production processes, a greater premium is placed on skills and cognitive ability. One study showed a rapid increase during the 1980s and 1990s in the proportion of the labor force engaged in tasks requiring interactive or analytical skills, as opposed to tasks based more on following prescribed rules. Thus firms have an incentive to undertake more extensive screening of prospective employees and provide more continuing education and training to those on the payroll. Job rotation can serve as another way of improving employees' understanding of the firm's processes, thereby enhancing their ability to solve problems and improve productivity.

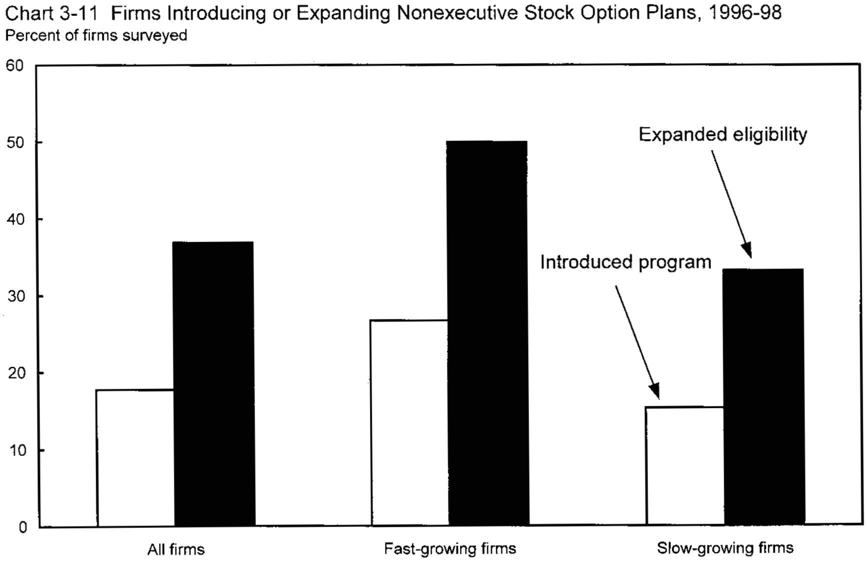
Much of this shift in decisionmaking authority to production workers began before the recent surge of investment in information technology. In the 1980s the high performance of Japanese manufacturing and the competitive threat it posed led many U.S. firms to experiment with or adopt Japanese-like practices. These practices have become even more valuable as firms have made large investments in information technology that complement their human resource investments.

A second major complementary change is the greater use of performance-based pay. Various incentive pay schemes—from production-based pay to profit sharing to stock option plans—have been designed to improve employee motivation. A 1998–99 survey found that 63 percent of respondent firms used some form of variable pay for nonexecutives. Between 1987 and 1999 the use of profit sharing and other performance-based incentives at Fortune 1000 firms increased from 26 percent to over 50 percent. These incentives perform two functions. First, they motivate employees to improve firm performance, because the employees share in the resulting monetary rewards. Second, they provide a screening function, as more highly skilled and more motivated employees are more likely to be willing to work in firms where pay is based on performance. One study of finishing lines in the steel industry found that lines with a set of supporting innovative work organization and incentive practices reduced downtime by 7 percentage points.

Stock option grants are a particularly important form of incentive pay. They have been a part of executive compensation for years, but grants for nonexecutive personnel are a relatively new phenomenon. Although only 5 percent of all nonexecutive employees in publicly held firms received stock option grants in 1999, the proportion rises to almost 27 percent for those earning more than $75,000 a year. Moreover, the use of this compensation vehicle appears to be diffusing rapidly. A 1998 survey of 415 firms found that 34 percent had some type of stock option plan for nonexecutives. Although this was not necessarily a representative sample of all U.S. firms, other studies reach similar findings. This study also found that, of the 88.4 percent of firms that reported the use of any type of variable pay, 17.7 percent indicated that they had introduced a stock option plan within the past 2 years (Chart 3-11); 8.2 percent reported introducing profit sharing, and 13.8 percent offered bonuses. Eligibility for stock options was also broadened more rapidly than were plans for profit sharing or bonuses. A study of 125 firms that accounted for about 75 percent of 1997 market capitalization of firms in the Standard & Poor's 500 index estimated the value of these grants at about 4 percent of total compensation in 1998.

The use of stock options is spreading, especially at fast-growing firms.

Chart 3-11 Firms Introducing or Expanding Nonexecutive Stock Option Plans, 1996-98



Source: David Lebow, Louise Sheiner, and Martha Starr-McCluer, "Recent Trends in Compensation Practices," Federal Reserve Finance and Economics Discussion Paper, 1999.

The use of stock options appears to be highly concentrated in the high-technology sector. Stock options might be a preferred method of compensating workers in high-technology firms because they allow firms with low current (but high expected future) cash flows to offer higher compensation than they otherwise could. Stock options may also elicit greater worker effort and productivity by tying the worker's compensation to the firm's long-term performance. There is little actual evidence, however, on the performance effects of stock options. One study did find that the presence of an employee stock ownership plan or a stock option plan increases labor productivity at the establishment level, after controlling for other aspects of workplace practices and establishment attributes. Another study found that, after controlling for firm size and industry classification, sales per worker in 1997 were higher in firms that had implemented a broad-based employee stock option plan. However, it is too early to draw firm conclusions on the net effects of options on compensation, especially because the expansion in their use came at a time when stock prices, and hence the value of stock options, were increasing. The effect of employee stock option plans may be substantially different when stock prices are flat or falling.

Significant changes in human resource practices have been documented in several other industries, including steel, automobiles, apparel, and customer call centers. These changes have allowed firms to make better use of the new information technology that has recently become available.

Changes in Firm Boundaries

Information technology, along with the complementary human resource practices just described, has also had important effects on firm boundaries in many industries. (A firm's "boundary" is simply the line between the set of activities a firm performs for itself and the set of activities that it pays other firms to perform for it.) Vertical boundaries describe the firm's relationships with its suppliers and its customers: vertically integrated firms manage their own supply lines and have their own marketing and distribution networks, whereas firms that are not vertically integrated prefer to purchase supplies from independent dealers and to contract out their marketing and distribution to retailers. Horizontal boundaries describe the firm's relationships with its rivals: some markets are dominated by a few large, horizontally integrated firms, whereas in others many smaller firms compete for customers.

Information technology has frequently led to tighter, more closely integrated relationships between firms and their suppliers and between firms and their customers, without necessarily leading to full vertical integration. Indeed, the declining cost of exchanging information between firms has led many firms to outsource functions previously performed in house. At the same time, information technology has led to substantial consolidation in industries such as telecommunications and financial services, representing an increase in horizontal integration, although in some cases changes in regulation and competition have been more important motives for consolidating.

Supplier Relationships

Today's consumer goods pass through complex supply chains, which the application of information technology can make more efficient. In many industries today, the supply chain involves a number of firms performing a variety of distinct functions, all of which are necessary to bring a product to market. These firms may create or extract primary materials, design and assemble those materials into more complex components, transport intermediate and finished products, or offer them for sale to the consumer. The efficiency of this system depends on the speed with which it delivers final products to consumers, the amount of inventory that is locked up in the supply chain at any given time, and, of course, the efficiency of each firm in the chain.

Information technology, combined with changes in business practices, has enabled firms to reduce costs and increase efficiency in their supply chains, as is evident in retail trade. In the retail sector, sharing of point-of-sale data between a firm and its suppliers, a practice that received considerable attention in the 1980s, has become increasingly widespread, improving the flexibility and efficiency of distribution systems and lowering costs for consumers. For example, over 97 percent of grocery stores now use scanners to collect point-of-sale data. Efficient customer response (ECR) systems that share this point-of-sale data with suppliers to improve the efficiency of the supply chain were introduced in 1992. These systems take into account customer demand in an individual store as well as the complete economics of the supply chain. One recent study showed that ECR adoption was associated with higher productivity: firms that had gone further in their efforts to adopt ECR had higher sales per labor hour and per square foot and turned over their inventories more often than other firms. The study was not able to establish the direction of causation, however. In many industries these changes have redefined, or promise to redefine, the relationship between a firm and its suppliers.

More drastic improvements in efficiency, driven by Internet technology, are occurring in other industries. In some cases, new firms have entered the market to simplify complex purchasing processes. For example, in the highly specialized life science research supply business, scientists at tens of thousands of different laboratories in hundreds of firms and universities purchase over 1 million distinct products manufactured by hundreds of firms to conduct their experiments. For a laboratory scientist, ordering these products has traditionally involved searching through 500-page catalogues from multiple suppliers, filling out forms to send to the purchasing department, and faxing or phoning in an order. The typical cost of processing orders in this way, including paperwork and employee time, has been estimated to be around $100 per order. Using the Internet, one firm has created an on-line marketplace with over 1 million products and has streamlined the ordering process and the interface between the purchasing department and the scientist. This technology promises to reduce the total cost of placing an order to about $10.

On-line business-to-business (B2B) exchanges have emerged to seek even greater efficiencies in the industrial procurement process. Some of these exchanges are industry-specific, whereas others offer a broad range of industrial products, commodities, and services to multiple industries. B2B exchanges offer a range of transaction tools, such as auctions, centralized clearing for payments, credit information about trading partners, and other custom services that allow greater efficiency in procurement. One on-line exchange claims to have saved customers $2 billion during its 5 years in operation. An on-line exchange for the steel industry boasts a clientele of 220 mills, 647 service centers, 909 fabricators, 352 distributors, and 626 trading companies.

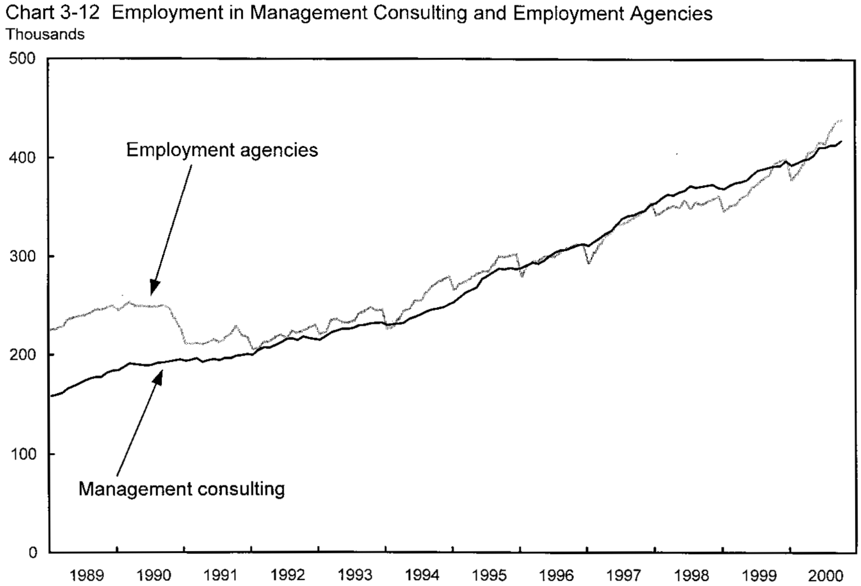
One market research firm estimates that B2B sales over the Internet rose to $200 billion in 2000, from about $40 billion in 1998. Projections vary widely but tend to agree that this dramatic growth will continue in the near future. The efficiencies of B2B commerce are likely to extend the performance gains already realized in aggregate inventory statistics. Inventories in a wide range of industries have fallen steadily over the past decade, with significant declines in apparel and department stores and among manufacturers of industrial and electronic goods. For example, in the early to mid-1990s, firms in the apparel industry reduced their inventories by an average of 1.2 percent per year, and their inventory-to-sales ratios by an average of 5.2 percent per year, by adopting information technology and a modular, team-based system of production that improved flexibility.

Many firms are outsourcing, or contracting out, functions they previously performed themselves. Indeed, outsourcing has grown rapidly. Between January 1993 and October 2000, employment agency payrolls grew 99 percent, and management consulting services grew about 94 percent (Chart 3-12), while economy-wide employment growth was a much smaller 20 percent. Firms routinely outsource strategic development and the management of their information technology, human resources, and facilities operations to firms that specialize in these functions.

Firms choose to outsource for any of several reasons. Contractors that specialize in a particular function may have competitive advantages in performing these functions relative to in-house staff and service groups, and reducing operating costs is one of the most frequently cited reasons for outsourcing. Contracting out can contribute to a firm's productivity in other ways. By letting others provide services that are ancillary to the company's

Providers of outsourced services are employing more and more people.

Chart 3-12 Employment in Management Consulting and Employment Agencies



Source: Department of Labor (Bureau of Labor Statistics).

primary business, outsourcing allows management to focus its effort on doing its core business better. In addition, outsourcing provides firms with access to expertise that would be costly and time-consuming for the firm to recruit and bring on staff. This expertise can also bring in new ideas and innovations learned from other firms in the industry or beyond. Finally, firms can use outsourcing to achieve greater flexibility: they can quickly access capabilities as needed and with less investment in physical plant and less overhead. At the same time, however, outsourcing carries risk for firms and for their employees. Management may lose control of key operational functions or skills. And some temporary employees may be paid less than regular employees and be less likely to receive benefits such as health insurance.

Firms have other choices besides outsourcing and in-house production. They can engage in strategic alliances, which are long-term agreements between firms to share facilities, expertise, and other resources to accomplish joint goals. U.S. firms have been particularly active in this area, accounting for about half of all alliances among firms based in OECD countries during the 1990s. Strategic alliances, like other long-term contracts, allow firms to combine some aspects of their operations without incurring the costs of full integration. For example, an alliance with a key supplier can help stabilize the supply chain, whereas a marketing alliance may allow firms producing complementary products to pool their resources for greater joint gains. (A movie studio might form an alliance with a fast-food restaurant chain to promote a new release, for example.) Also, as discussed earlier in this chapter, firms may ally in order to develop a new technology or to exchange existing technical capabilities.

Customer Relationships

Information technology has also enabled firms to communicate more closely with their customers, and thus to be more responsive to customer preferences and to produce goods and services that reflect those preferences. Firms are using information technology in a number of ways to improve marketing and customer service. As the costs of computing and data storage have fallen, firms' efforts have shifted away from mass marketing, in which each potential consumer receives the same message, to more interactive marketing (sometimes called micromarketing). Interactive marketing uses information about a customer's prior purchase behavior, credit history, location, and income to provide that customer with information about products he or she might be likely to purchase. Database technology has made this type of marketing feasible on a broad scale. On-line book and music retailers now provide their customers with real-time recommendations for additional purchases based on the customer's purchase history, and grocery stores use customer data to tailor the choice of cents-off coupons offered at checkout. The same database technology, combined with reduced costs of communication, has enabled firms in a number of industries to provide customer service at lower cost over the phone. Firms in industries from telecommunications to financial services to consumer goods have established telephone call centers to handle customer questions and to provide product support. Information technology allows these centers to be based almost anywhere in the world, and service representatives at these centers to access the entire history of a customer's account during the call. The ability to store and retrieve these data quickly has made customer information a strategic asset, one that firms are increasingly looking to take advantage of.

The Internet is radically altering how producers and sellers of consumer goods interact with their customers. A manufacturer or retailer can now communicate with customers anywhere in the world at relatively low cost. A number of firms have taken advantage of this capability, offering products and product information via the Internet. Consumers with access to the Internet can now do comparison shopping at very low cost before leaving the house or placing an on-line order. Internet sales to consumers reached $17.1 billion in the first three quarters of 2000 (but still account for less than 1 percent of all retail sales). The Internet has also created whole new transaction mechanisms, such as on-line auctions. A significant fraction of all Internet consumer auctions are for secondary goods and remainders. This suggests that total trade in these goods may be on the rise.

Market Structure

Technology has also affected the structure of many markets, making some more highly concentrated while leading others to become more fragmented. Markets for many software products and information services, for example, have been dominated by big players with large market shares. Ownership of a particular technology standard is often an important source of competitive advantage if that technology cannot be imitated, and this can lead to market concentration. In the United States, information technology standards are often established in a decentralized manner, through the free play of the market, rather than through a centrally coordinated effort. Markets with strong network effects are often characterized by "tipping." When it becomes apparent that one technology has a large enough lead, the market may "tip," with nearly all new consumers from that point forward adopting the dominant technology. In such winner-take-all (or winner-take-most) markets, a firm faces crucial decisions about whether to make its product compatible with past and future generations of products, and whether to base its product on open or proprietary technology. Intense early competition to build a base of loyal users may result. Firms may also use strategic product preannouncements to establish a stake in a new market and head off competition.

This propensity of markets with network effects to tip poses challenges for regulators and antitrust authorities as one or a few firms begin to dominate. It also encourages cooperation among competitors within an industry to promote a standardized technology. In cases where formal alliances or joint ventures are created, the costs of developing intellectual property are often shared, as are marketing expenses. As the U.S. legal code and U.S. antitrust authorities have recognized, such collaboration need not preclude vigorous competition in the product market.

In industries such as telecommunications, energy, and financial services, many markets have become more concentrated as firms combine their operations through mergers and acquisitions. In financial services the primary sources of structural change have been information technology and deregulation. For instance, ever since passage of the Bank Holding Company Act of 1956, geographic restrictions on banks have been slowly lifted, enabling them to expand gradually across State lines. Although barriers to interstate banking were not completely removed until the enactment of the Riegle-Neal Interstate Banking and Branching Efficiency Act of 1994, regional and interstate pacts enabled bank holding companies to operate across State lines. One study estimates that, by 1994, a bank holding company in a typical State had competitive access to nearly 70 percent of U.S. gross domestic banking assets.

As banks have expanded, they have also begun to consolidate. Over a third of all banking organizations nationwide disappeared between 1979 and 1994, even as total banking assets continued to increase. Between 1988 and 1997 the numbers of stand-alone banks and top-level bank holding companies both fell by almost 30 percent, while the share of U.S. banking assets held by the top eight banking organizations rose from 22.3 percent to 35.5 percent. In 1998, 4 of the top 10 U.S. "mega-mergers," based on market value, occurred in financial services. These changes are not confined to the United States: two Japanese bank mergers currently pending will create the two largest banks in the world, with about $2.5 trillion in assets between them.

Deregulation is thus an important spur to geographic diversification and consolidation. Past geographic restrictions on competition may have allowed inefficient banks to survive, and consequently the gradual removal of these restrictions has transformed the structure of the industry. One study shows that bank efficiency improved substantially as restrictions on intrastate branching and interstate banking were removed. As a result, the share of deposits held by subsidiaries of out-of-State bank holding companies increased from 2 percent in 1979 to 28 percent in 1994. Meanwhile, the Glass-Steagall prohibition on combining commercial and investment banking in the same enterprise is slowly being lifted. In 1987 the Federal Reserve Board began permitting bank holding companies to engage in limited nonbank activities through so-called Section 20 affiliates. Section 20 activities were originally limited to 5 percent of a subsidiary's total revenue, but the limit was raised to 10 percent in 1989 and 25 percent in 1996.

In 1999 many of the Depression-era restrictions on banks were formally removed with passage of the Financial Modernization Act (also known as the Gramm-Leach-Bliley Act). This legislation lifts these regulatory barriers by creating a uniform regulatory framework governing affiliations among different financial services institutions, and by expanding the range of investments available to these firms. The new law allows banks, security firms, and insurance firms to affiliate under a new rubric, that of a financial holding company. By November 2000, 456 such companies had been formed, with assets totaling 13 percent of all U.S. financial sector assets.

Expansion, consolidation, and diversification can bring about performance improvements by allowing financial institutions to realize economies of scale. These scale economies are largely driven by innovations such as new financial instruments, new risk management techniques, automatic tellers, improved back-office operations, phone centers, and Internet banking. Recent evidence indicates that bank efficiency has indeed improved, particularly when new banking organizations have been created through mergers and acquisitions. Large banks have also made significant improvements in their abilities to manage risk; the costs of financial distress, bankruptcy, and loss of charter have been reduced. Moreover, despite fears that large banking organizations would focus exclusively on large customers, bank mergers and acquisitions have not adversely affected small business lending. The Department of Justice's Antitrust Division, along with the Federal Reserve Board, is careful to consider the impact of mergers on the communities to be served before approving any reorganization.

Explaining Changes in Firm Boundaries

As these examples have shown, firms are tightening some supplier and customer relationships, outsourcing other aspects of their operations, and in many cases consolidating business activities with former rivals. These and other changes in firm boundaries are best understood within the contractual framework associated with the Nobel Prize–winning economist Ronald Coase. Coase was the first to explain that the boundaries of an organization depend not only on its productive technology but also on the costs of transacting business. In the Coasian framework, the decision whether to organize transactions within the firm or on the open market—the make-or-buy decision—depends on the relative costs of internal and external exchange. Use of the market mechanism entails certain costs: discovering the relevant prices, negotiating and enforcing contracts, and so on. Within the firm, entrepreneurs may be able to reduce these transactions costs by coordinating these activities themselves. However, internalizing brings other kinds of transactions costs, namely, problems of information flow, preserving incentives, monitoring effort, and evaluating performance. The boundary of the firm, then, is determined by the trade-off, at the margin, between the relative transactions costs of external and internal exchange. In this sense a firm's boundaries depend not only on technology but also on organizational considerations, that is, on the costs and benefits of various contracting alternatives.

The above examples suggest ways in which information technology may alter these boundaries by influencing transactions costs. In the case of supplier relations, communications and coordination with suppliers is facilitated by e-mail, automated information exchange, and particularly by B2B Internet use, all of which should reduce firms' tendency to be vertically integrated. However, at the same time, information technology also reduces the costs of coordinating activities within the firm, so the net effect on vertical boundaries is ambiguous. Moreover, information technology may lead to expanded horizontal boundaries, as high-speed communications across plants in different countries now allows firms to grow as they exploit their comparative advantages in global markets. Perhaps for these reasons, it is difficult to detect any economy-wide changes in vertical or horizontal boundaries, although distinct patterns are discernible within particular industries.

Competition and Strategy

Firms face a variety of strategic decisions. So far this chapter has discussed the decisions surrounding the adoption of information technology, reorganization of the workplace, and the fixing of the firm's vertical and horizontal boundaries. These and other decisions are made with the goal of outperforming rivals, that is, of achieving what the strategic management literature calls sustained competitive advantage. An important source of sustained competitive advantage is the possession of unique resources, such as firm-specific knowledge or capabilities, an installed base of users, valuable patents, or a popular proprietary standard. In the new, knowledge-based economy, such intangible resources have become increasingly important.

Intangible Capital

Success in the New Economy relies on intangible capital. In a market characterized by intensified competition (driven by globalization and deregulation) and rapid product and service innovation, corporations must innovate continuously—creating new products or services and producing them with new, more efficient processes—to stay competitive. Thus, intangible assets—organizational practices, human resources, R&D capability, and reputation—are now much more prominent features of a firm's competitive strategy, because they are the foundation for innovations that lead to success. New organizational practices provide the ability to respond quickly to new opportunities. Appropriate human resource practices, such as an emphasis on training and the design of appropriate incentives, provide firms with employees who are able and eager to recognize, create, and develop opportunities. An R&D program that is good at conceiving ideas and converting them into products provides a stream of innovations. A favorable reputation, embodied in brand names, trademarks, and customer loyalty, can provide the trust on the part of customers that encourages their acceptance of a firm's latest product innovations.

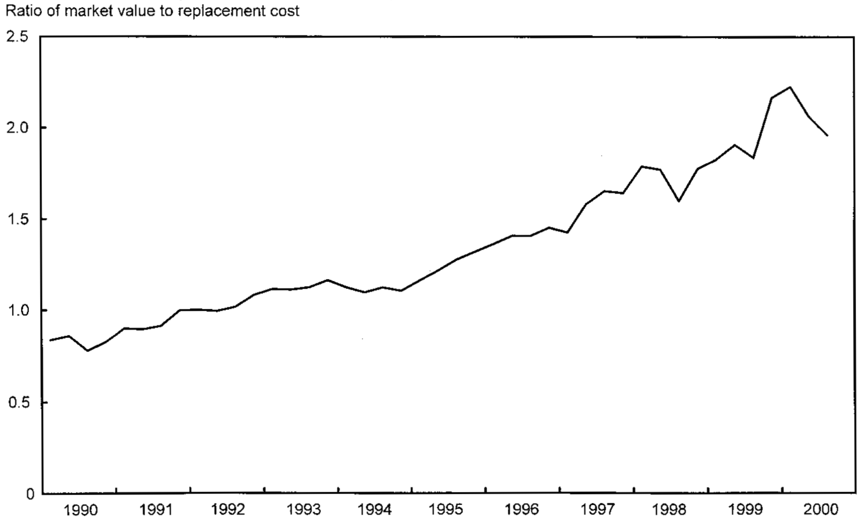
One indicator of the importance of intangible capital is what economists call Tobin's q, which is the ratio of a firm's market value to the cost of replacing its underlying tangible capital. One interpretation of a high q is that a large part of the firm's value derives from intangible capital. As Chart 3-13 shows, Tobin's q for publicly traded U.S. firms rose throughout the 1990s. This is consistent with an increasing importance of intangible capital.

Information Goods

It is said that information, not tangible products, is the most important economic good in the New Economy. Of course, so-called information goods, from books, music, and television programs to the yellow pages and real-time stock quotes, have long been important to the U.S. economy.

The increase in the market value of firms relative to the value of their physical assets suggests that intangible assets such as knowledge have become more important.

Chart 3-13 Tobin's *q* in the Nonfinancial Corporate Sector



Source: Council of Economic Advisers calculations based on data from the Board of Governors of the Federal Reserve System.

During the last decade, however, innovations in duplication, storage, and transmission have sharply reduced the cost of delivering information goods to consumers. These falling costs have led to increased entry by firms seeking to deliver new information products and have led incumbent firms to revisit their strategies for maximizing the value of the information they create and distribute.

The production of information tends to be characterized by high fixed costs and low variable costs; computing and the Internet reduce the latter nearly to zero. When consumers' preferences are relatively similar, markets for information goods may be highly concentrated. For example, few markets are served by more than two yellow pages providers. However, when consumers' preferences vary widely, multiple producers may enter the market and find it profitable to focus on small groups of consumers. For example, although the major television networks still account for over half of viewership in prime time, hundreds of other cable television channels now cater to specific viewer tastes.

The low cost of distributing information via the Internet has led information providers to rethink yet again their strategies for reaching consumers. Many magazines and newspapers now offer free on-line versions of their paper products. Some of these firms offer additional unique on-line content for free; others offer premium services such as customized content for an additional fee. Some information providers have integrated with distribution channels such as cable operators and even Internet access providers, whereas others have chosen to remain independent.

Internet Retailing

For retailers and manufacturers of branded consumer goods, the Internet has created a whole new distribution channel. This has raised significant issues about how to compete, especially for firms with investments in physical distribution infrastructure. For manufacturers that have traditionally sold through intermediaries such as department stores or specialty retailers, the Internet makes direct sales to customers possible. However, for these firms to sell directly through the Internet, they must undertake activities that are new to them, such as retail billing, order fulfillment, delivery, and handling of individual returns. The potential profits from additional sales at retail prices must be measured against the cost of developing these new capabilities and against potential loss of sales through existing channels. A major sports apparel producer now sells through four different channels: sporting goods stores, department stores, company-owned stores, and the Internet. For traditional bricks-and-mortar retailers, on-line sales may compete directly with their own retail business. This has led some firms, such as one large book retailer, to separate their on-line and bricks-and-mortar operations in order to offer greater flexibility to both. Other retailers have chosen hybrid strategies, allowing customers to buy on line but funneling all returns and customer service through existing stores. Some bricks-and-mortar retailers have forged partnerships with on-line retailers to satisfy the needs of on-line shoppers.

Understanding Performance Gains

This chapter has documented the extensive changes in firm organization and strategy brought about by technological change. Ultimately, however, to explain the effects of information technology on the aggregate productivity gains reported in Chapter 1, these technological and organizational improvements must be linked to realized performance gains. Fortunately, new studies are beginning to document the performance effects of information technology and associated organizational changes at individual plants and firms. This evidence strongly supports the idea that the new technology, when combined with the appropriate organizational structures, has improved performance, and did so especially in the 1990s.

How Do Technology and Organizational Change Improve Performance?

As already emphasized, investments in information technology work best when combined with complementary changes in business and production practices. Performance improvements are most likely to be realized when firms couple these investments with changes in basic business practices, such as in job design, organizational structure, and interactions with customers and suppliers, and changes in human resource practices, such as in incentives and decisionmaking authority, that are designed to allow employees to use the new technology most effectively. Differences in the patterns and rates at which plants adopt these complementary practices may explain why the productivity effects of investments in information technology did not come immediately and still have not been realized by all firms.

The lag and variability in productivity gains after investing in information technology may be due to the time it takes for employees to adjust to the new technology. Implementing automated equipment initially causes disruption, as employees must learn new practices and understand that the operating procedures and priorities in place under the old technology may not be appropriate with the new technology. Introducing the newly needed skills into the work force—either by retraining or by hiring new workers with the appropriate skills—takes time, and productivity can fall during the transition. For instance, the introduction of electronic controls into automobile engines, transmissions, and auxiliary equipment and the development of computerized diagnostic equipment forced some mechanics to learn new skills. Several studies note that the disruptions caused by retraining can be so severe that firms choose to implement new technologies in greenfield sites—newly built plants with new employees who do not have to unlearn the old practices.

A second reason for the lag and variance is the need to match organizational structure to technological capabilities. In particular, giving employees authority to make decisions on workflow and machine scheduling, structuring employee compensation systems to align employees' interests with those of the firm, and implementing teamwork structures that effectively use employee skills all can increase the productivity of information technology. Those plants that adopt complementary human resource practices along with information technology tend to see greater performance improvements. For example, precision metal-cutting plants that redesigned work responsibilities to allow the operators to perform program editing were found to be 30 percent more efficient than plants where no production workers were given these responsibilities.

Research on information technology–related productivity at the firm level is difficult, in part because investment in the new technology is difficult to measure. However, a few studies have assessed the impact of such investments at the firm level. These also suggest that information technology, when combined with complementary human resource practices, can lead to performance gains. One study of the use of information technology in a nationally representative sample of over 1,600 firms found that increasing the share of the production work force that uses computers from 10 percent to 50 percent increased labor productivity by 4.8 percent. When increased computer utilization was coupled with profit sharing and implementation of employee involvement practices such as self-managed teams, labor productivity rose by another 6 percent in nonunion plants and 15 percent in union plants. Another study, this one of service and sales teams at call centers, found that self-managed teams improved sales productivity by 9.3 percent, and introducing new technology improved it by 5.3 percent. But when new technology and self-managed teams were combined, the result was an additional 17 percent rise in productivity above and beyond the individual effects. Although these studies cannot establish definitive causal relationships, the examples described in this chapter strongly suggest that information technology, when combined with appropriate organizational practices, can improve performance.

The Dynamics of Market Competition

The New Economy is characterized by both high profitability and high risk. Over a hundred new e-commerce startups have already shut their doors. Others, however, have made inroads against the established firms in their industries, and some have even transformed their industries.

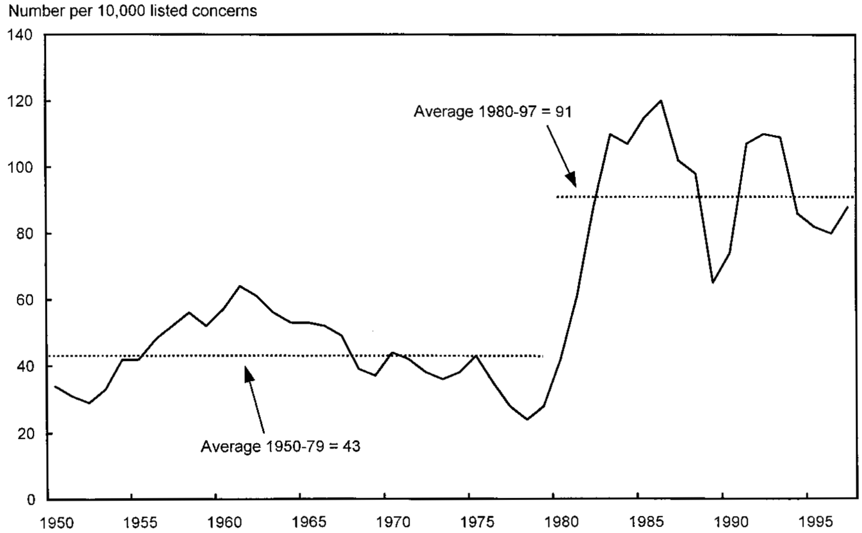
Competition and Creative Destruction

Market competition is a dynamic process whereby entrepreneurs constantly launch new companies to challenge existing ones, occasionally replacing them but just as often failing. This process—what the economist Joseph Schumpeter called creative destruction—is apparent in the U.S. economy today. As Chart 3-14 shows, the remarkable growth of the U.S. economy in the 1990s brought no reduction in business failures. Throughout the current expansion, business failures have hovered near their post-1980 average.

As these statistics suggest, today's firms are subject to remarkably intense competitive pressure, from both domestic and foreign sources. Nonetheless, corporate profits have exhibited strong growth, rising in real terms at a 5.7 percent annual rate from 1993 through mid-2000. This compares more than favorably with the period between 1980 and 1992, when real corporate profits rose at a 2.2 percent annual rate, and with the period between 1950 and 1992, when real corporate profits rose at a 3.2 percent annual rate (Chart 3-15). In short, a high rate of business failure is not necessarily a sign of economic weakness. Rather, it may simply reflect the market-driven process of shifting resources and adjusting the structure of production to meet consumers' changing needs.

The rate of business failures remained high in the 1990s even as the economy grew, reflecting a dynamic, competitive market economy.

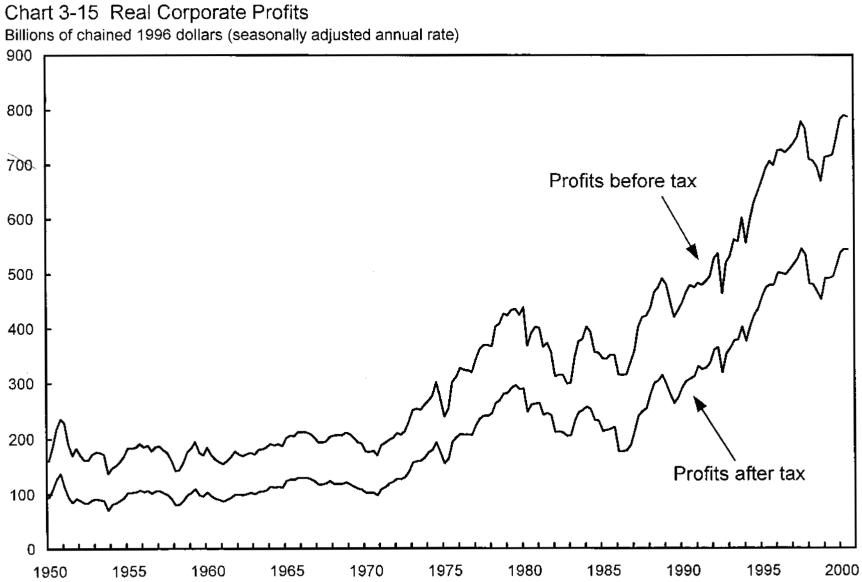
Chart 3-14 Business Failures



Source: The Dun & Bradstreet Corporation.

Real corporate profits rose dramatically in the 1990s.

Chart 3-15 Real Corporate Profits



Source: Department of Commerce (Bureau of Economic Analysis).

The Impact of Globalization

Along with the technological and organizational changes that this chapter has described, increasing global trade has made markets more competitive, with dramatic effects on firm behavior and performance. If a firm is exporting and competing in a variety of markets, it might be forced to improve its performance in order to penetrate overseas markets with strong domestic suppliers. Likewise, an increase in imports may lead domestic industries to search out ways to be more efficient, ultimately making them better at competing with foreign producers.

Evidence from the manufacturing sector suggests that good firms become exporters. Less clear is the answer to the opposite question: does exporting make a firm better? At the firm level there appears to be no significant causal link between exports and productivity. Microeconomic evidence from the Republic of Korea and from Taiwan reveals few industries where it can be argued that exporting alone aids performance. However, aggregate data show a correlation between trend productivity and export demand: an economy that exports more will likely have higher aggregate performance than one that exports less. This relationship appears to be stronger for high-technology industries. Nonetheless, the effect is smaller than that found for an equivalent increase in domestic demand. It could be that firms find it difficult to meet a wide variety of foreign regulations and satisfy a wide range of foreign preferences while maintaining efficiency.

Increased import competition is also associated with an increase in trend productivity. Combined with the observed link between export demand and productivity, this suggests that the economy as a whole allocates resources better when subjected to global competition. In part, this may be because imports spur imitation and innovation: a new foreign good introduced into the United States creates new demand, which challengers then seek to capture or duplicate with products of their own. Evidence from Japan suggests that it was import competition, not increased exports, that boosted the Japanese economy during its high-growth period from 1964 to 1973. A study of the aftermath of Chile's massive trade liberalization in the 1980s found that productivity in import-competing firms improved an average of 3 to 10 percent more than that in firms producing nontraded goods.

Conclusion

Technology has been a driving force behind the performance gains that are associated with the New Economy. With advances in information technology, firms have accelerated their investments in the new technology. It appears that sustained investment in information technology began to pay off handsomely in the 1990s, in the form of higher productivity within and across sectors. But it takes time for firms to realize these performance gains. They must first integrate information technology into their business or production processes, often through the development of highly specialized software. They also face important organizational and strategic choices about the best uses of new technologies and the increased availability of information. At the same time, increasing global competition and deregulation have given firms the incentives and the opportunities to seek ways of accelerating their performance.

Not all firms will be equally successful at implementing technological and organizational changes, and cyclical factors will diminish the gains at times. As discussed above, new firms have been important drivers of change, particularly in the information technology sector. However, innovation is by nature a risky endeavor, and many new ventures will fail. Equity values will continue to fluctuate. Entrepreneurs, investors, and workers must be prepared for the disturbances that typically accompany economic change. Moreover, the economy as a whole will continue to experience the rise and fall of the business cycle, making underlying productivity trends difficult to discern.

Although the impressive performance of the New Economy is ultimately due to the creativity and hard work of market participants, U.S. policies have helped create an environment that encourages entrepreneurship. The United States places relatively few restrictions on the movement of capital and labor, so that firms and individuals can respond when profit opportunities arise. The United States also imposes relatively low tax rates, so that individuals can realize the rewards of their innovation and effort. Extensive and relatively unfettered capital markets in the United States give entrepreneurs access to the financial resources they need to innovate. The U.S. government has practiced fiscal restraint, reducing interest rates and freeing capital for private sector use. And U.S. policies have provided direct support for R&D, along with indirect support through tax incentives for private sector investments. These policies have proved extremely valuable to firms and industries, and it is essential that they be continued.