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ABSTRACT

Job loss through technological advancement, particularly technologies based on microelectronics, is increasing for all economic sectors in a nation already hard challenged in world and domestic markets for goods and services. But assessing technology's employment impact remains difficult not only because of its direct and indirect effects and income and price effects, but also because of the net impact issue. Whether technology destroys more jobs than it finally creates is unclear; it may simply lower employment growth. One factor is clear, however: past labor displacement has resulted from a reduced demand for specific services, from the introduction of machines, or from a substitution of foreign for domestic goods. Between 1972 and 1980, employment in 50 out of 235 occupations declined by 2 million jobs, and in 1983 Atari laid off 1,700 American workers and moved production overseas. But technology has also created jobs, especially in computer-related industries. Nonetheless, much evidence suggests that types of jobs both eliminated and created are generally low-skill and low-wage, and that new technologies threaten even more job displacement, both skilled and unskilled. One forecast estimates 20 million job losses by the year 2000. Whether economic growth can offset the trend cannot be predicted. (KS)

Institute for Research on Educational Finance and Governance

SCHOOL OF EDUCATION STANFORD UNIVERSITY

Project Report No. 84-A12

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This paper is the third report produced under the IFG Project, "The Educational Consequences of High Technology," directed by Henry M. Levin and Russell W. Rumberger. The previous two papers, "The Educational Implications of High Technology" and "Forecasting the Impact of New Technologies on the Future Job Market," can be ordered from IFG.

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Abstract

Technology creates jobs, but it also eliminates them. These two outcomes raise two important questions: Does technology create more jobs than it destroys? Does technology create more higher-skilled jobs than it destroys? Evidence suggests that future technologies may provide different answers to those questions than past technologies. In the past, technology primarily displaced unskilled, physical labor in some sectors of the economy, while economic growth created more than enough jobs to offset those displaced by technology. In the future, however, technologies based on micro-electronics threaten to displace skilled, mental labor in all sectors of the economy, while continued increases in productivity may limit the ability of the economy to generate enough new jobs to offset those displaced by technology.

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> There is, of course, not a scrap of evidence in either theory or history to suggest that technological development won't increase employment and real incomes today just as it always has.
>
> -Bruce Bartlett, Executive Director,
> Joint Economic Committee of Congress (1984)

> For millions of Americans, job opportunities are being destroyed by a fierce combination of forces, the most threatening of which is technology. The time has come to worry about automation again. After 1990, when current technology has gone through more than half its expected development, it will take perhaps 75 percent of the work force to do 100 percent of the work.
>
> -Gail Garfield Schwartz and William Neikirk,
> The Work Revolution (1983)

Technology is transforming work throughout the economy. Many workers are now using computers, word processors, and other electronic products to perform their jobs faster and more efficiently. Other workers are simply being replaced by machines. Automatic teller machines are eliminating jobs for bank tellers. Robots are replacing a variety of workers on the assembly lines of American factories. Direct dialing equipment is greatly reducing the number of telephone operators. Even airline pilots are not immune to replacement by machines: the new generation of aircraft, the Boeing 757 and the 767, requires 2 instead of 3 persons in the cockpit.

Some people view these developments with great alarm. The loss of jobs due to machines is taking place in all sectors of the economy and appears to be accelerating. Even more alarming than the present trends are the ominous prospects for the future. The development and application of new machines, fueled by the greatly reduced price and greatly increased capacity of micro-electronics, promises no end to the replacement of men and women by machines. With recent unemployment levels already at very high levels, millions of workers could remain unemployed in the future.

It is not only the number of jobs being lost to machines that generates concern, but also the kinds of jobs. Past technological developments largely displaced physical labor on the farm, in the factory, and in the home. But new technological developments,

especially those based on micro-electronics, are largely displacing mental labor in all sectors of the economy. As computers become cheaper and more sophisticated, they will be capable of replacing workers in more sophisticated jobs. Not only bank tellers and telephone operators can be replaced by machines, but so can pilots and industrial designers.

Others see little reason to view these developments with any concern. Technology has always displaced workers from jobs in certain occupations and industries. But employment in other areas of the economy has always expanded to provide new jobs. The decline in agricultural employment during the first half of this century was accompanied by increased manufacturing employment. The service sector has more recently provided the bulk of new jobs as manufacturing employment has leveled off. While machines will always eliminate some jobs, economic growth will generate enough new jobs to absorb those workers in other sectors of the economy.

The fears and concerns about job loss from technology are not new. They began during the early days of the industrial revolution in England, as men began to be replaced by machines:

> Perhaps most obvious of all was the unemployment of displaced craft workers, only slowly absorbed by the expanding factories. Such unemployment (at this period) was only temporary, but was nevertheless serious to those displaced. Machines, it seemed, were the cause of that unemployment. They did work formerly requiring many hands. Small wonder that the craftsmen at times turned against these machines (Lilley 1965, p. 111).

Fears of job loss have continued ever since. The fears generally become more widespread during periods of high unemployment. They arose during the Great Depression. They arose again during the late 1950s and early 1960s as more and more factories began to automate and the national unemployment rate climbed to over 6 percent.

The concerns over job loss from technology during this last period grew from the ranks of union officials as their members feared for their jobs. Soon the concerns were voiced from government officials. President Kennedy stated at a press conference in 1962:

> The major domestic challenge of the Sixties is to maintain full employment at a time when automation is replacing men. It is a fact that we have to find over a ten-year period 25,000 new jobs every week to take care of those displaced by machines and those who are coming into the labor market (quoted in Dunlop 1962, p. 1).

These concerns prompted President Johnson to create the National Commission on Technology, Automation, and Economic Progress in 1964. It also generated a host of national conferences and widespread scholarly inquiry into the issue of technological unemployment.

As these deliberations began, the national unemployment rate dropped to under 5 percent. Not surprisingly, perhaps, most of the research produced in this period reached the same conclusions as the National Commission (1966):

> Thus technological change (along with other forms of economic change) is an important determinant of the precise places, industries, and people affected by unemployment. But the general level of demand for goods and services is by far the most important factor determining how many are affected, how long they stay unemployed, and how hard it is for new entrants to the labor market to find jobs (p. 9).

The concern over technological job loss has now resurfaced, triggered by the recent recession and the highest unemployment rate since the 1930s. But again many people view the recent displacement as only a temporary condition affecting workers in only certain sectors of the economy, such as steel and automobile manufacturing. The most common response to those displaced by machines is that the future should be no different from past periods of displacement: economic growth will eventually produce enough jobs to replace those lost to machines.

Yet the past may be a poor guide to the future. First, new technologies, based on sweeping developments in micro-electronics, are likely to eliminate many more jobs in the future than past technologies did. Past technologies largely eliminated unskilled jobs in agriculture, construction, and some areas of manufacturing. New technologies threaten jobs in the factory, on the farm, and in the office. Much of this displacement will take place in the service sector, where most new jobs have been created over the last few decades.

Moreover, these technologies threaten to displace high-level, mental jobs as well as low-level, physical ones.

Second, the economic environment in which these changes are taking place is also different from times past. The U.S. no longer dominates the world marketplace. Many nations, including developing countries, can now produce even sophisticated, technical products that compete with those produced in the U.S. The United States is thus being challenged in both the world market and the domestic market for goods. Foreign producers have already captured a large share of the domestic market in steel, automobiles, and consumer electronics.

American firms, in order to remain competitive, are setting up manufacturing facilities in other countries to take advantage of lower labor costs. This movement has been facilitated by technological developments in transportation and communication, as well as manufacturing techniques that allow low-skilled, low-wage labor to produce even the most sophisticated electronics devices. American workers not only must fear for their jobs because of technology, but also because of foreign workers paid by American companies.

This economic climate, together with the current fiscal problems of large budget deficits and high interest rates, may undermine the nation's ability to sustain enough economic growth to offset the loss of jobs from technology and the movement of jobs overseas.

The remainder of this paper examines the issue of technology and job loss in greater detail. First, it examines the problems in assessing the impact of technology on job loss and job creation. Then it examines the employment impact of technology in the recent past. Finally, it examines future employment effects and discusses why they will differ markedly from those that have taken place in the past.

Assessing the Employment Impact of Technology

Technology both destroys jobs and creates new ones. Although it is easy to identify particular cases where technology has had a positive or

negative effect on employment, it is much more difficult to identify and measure the overall outcome of these processes throughout the economy.

One difficulty is that technology affects employment both directly and indirectly. Direct effects are generally easy to identify. The introduction of automobiles, for example, created new jobs in the automobile industry and eliminated jobs for blacksmiths and wagon builders. In some cases the employment effects are due to a particular technology; in other cases they may be due to a number of interrelated or cumulative technical developments (Rosenberg 1982, Chapter 3).

Technology also affects employment indirectly. The increased use of automobiles helped to create jobs in petroleum, rubber, steel, and a number of other industries that provided goods used in their manufacture and services used to maintain them. While such indirect effects may be easy to identify, it is more difficult to assess the actual number of jobs created, especially since most are in other industries or sectors of the economy.

It is even more difficult to assess the income and price effects of technology. If technical improvements lower production costs, firms can lower prices and increase sales, thereby creating more jobs. Firms can also raise wages, which would increase consumer spending and sales of other goods and services in the economy. But again it is easier to identify this effect than to measure it. Many economists argue, for example, that technology has greatly increased the level of material well-being in contemporary economies (e.g., Rosenberg 1982). Economist Edward Denison estimates that advances in knowledge, including technology, together with other unexplained factors accounted for one-third of the nation's economic growth between 1929 and 1976 (Denison 1979, Table 7-1). Yet no one has been able to single out the contribution of technology alone.

Another difficultly is that other factors affect employment besides technology. Employment shifts can occur because of secular changes in consumer tastes or because of cyclical changes in consumer income.

Even more difficult than assessing the direct and indirect e[illegible]oyment effects of technology is assessing its net impact. It is

very clear that technology destroys jobs. And it is equally clear that it creates jobs. What is unclear is whether technology destroys more jobs than it creates. At this point, neither the theoretical literature nor the empirical literature is able to resolve that important issue. But the issue has attracted widespread research and debate.

As economist Robert Heilbroner points out in a review of the historical debate, the question of the employment impact of technology began with Adam Smith more than 200 years ago (Heilbroner 1962). Technology, according to Smith, was the key to creating the "wealth of nations." Through technical development and the division of labor, goods could be produced for lower cost, thereby increasing sales and ultimately employment. Other classical economists, David Ricardo and John Stuart Mill, challenged Smith's view. Mill argued that technology may increase production and wealth, but there is no guarantee that it will increase employment (Heilbroner 1962, p. 11).

The debate has continued ever since. But as Heilbroner points out, few economists have devoted much theoretical attention to this issue. Only recently has scholarly inquiry into the causes and consequences of technological development been undertaken (e.g. Rosenberg 1982; Stoneman 1983). Yet the question of the employment consequences of technology remains unanswered. Heilbroner (1962) argues:

> What still lacks is a conception of the technological progress sufficiently broad to comprehend its long-range and its short-range impacts, alive to its secular re-arrangements of society as well as to its mixed creative and disruptive effects on the economy. The objective may well exceed our grasp. But it is certainly the direction of inquiry toward which a review of the historical debate urges us (p. 22).

There have also been attempts to provide empirical evidence about the net impact of technology. Some of the evidence simply consists of historical data on long-run trends in employment, both within sectors of the economy and in the economy as a whole. But as recent government data illustrate, there is no systematic relationship between rising productivity, which is at least partly attributable to technology, and employment in American industry. In some cases rising productivity is

associated with declining employment, while in others it is associated with rising employment (U.S. Bureau of Labor Statistics 1983, p. 47).

For the economy as a whole, total output has generally grown faster than productivity, so total employment in the United States has continued to rise. Between 1948 and 1981, for example, economic output increased 3.3 percent per year, while productivity (output per hour) increased 2.4 percent per year (U.S. Bureau of Labor Statistics 1983, Table 4). Employment increased 42 million over this period (U.S. Council of Economic Advisors 1984, Table B-29). But such evidence simply demonstrates that sufficient economic growth can offset any job losses due to technology, not that technology alone necessarily increases employment.

The inability to determine the net employment impact of technology also makes it difficult to determine the effect of technology on unemployment. Much of the concern associated with technology comes from workers who fear for their jobs. The term "technological unemployment" has been used to describe unemployment attributable to technology. Yet technology may cause few workers to become unemployed even if it eliminates many jobs. Technology may simply cause slower employment growth or even no employment growth in an occupation over time. Much of the actual displacement that does occur can be accommodated through turnover and retirement. On the other hand, workers who initially lose their jobs because of slack demand may never be rehired because of automation. Many unemployed autoworkers are now in this position.

While changes in employment or unemployment cannot be attributed to technology solely, unemployment in the United States has nonetheless increased over the last three decades. The U.S. unemployment rate averaged 4.5 percent during the 1950s, 6.2 percent during the 1970s, and over 8 percent during the first three years of the 1980s (Figure 1). These figures suggest that the economy has not been able to generate enough jobs for the U.S. labor force. Unemployment, whatever its causes, remains a serious problem.

Although no comprehensive data exist that measure the overall employment impact of technology throughout the economy, a variety of

available evidence can illustrate where past displacement and job growth related to technology has taken place in the economy and what areas of the economy are likely to be affected in the future. A review of this evidence suggests that displacement is likely to become more widespread in the future.

Recent Job Loss from Technology

Job Displacement

Technology can displace labor by reducing the number of people used to produce a given level of output or by reducing the skill levels of the labor required. Both forms of displacement will reduce the labor costs of production. Of course, not all technical innovations displace labor. Some innovations may save material costs or improve the efficiency of capital. But many tend to displace labor, at least in the United States. A survey of process innovations introduced in the U.S. between 1945 and 1974 identified 61 percent as labor saving (Davidson 1976, Table 2).

The following analysis focuses on the number and types of jobs displaced by technology. A subsequent paper will examine the impact of technology on the skill levels of jobs.

Technology can eliminate jobs in several ways. First, it can reduce or eliminate the demand for particular goods or services due to the substitution of competing goods or services. Second, it can reduce employment within particular occupations or even an entire industry through the introduction of machines and processes that reduce labor requirements. And finally, it can facilitate the substitution of foreign-produced goods for those produced domestically. Recent job losses in a number of occupations can be attributed to each type of displacement.

Table 1 shows the occupations with the largest declines in employment between 1972 and 1980. Total employment in the economy increased by 15 million over this period, raising employment in most occupations. But employment in 50 out of 235 occupations declined by

more than 2 million jobs, with more than 1.5 million jobs lost in only 10 occupations.

Two of the occupations that suffered declines in this period were in private household service--cleaners and servants and child-care workers. More than 300,000 jobs in these two occupations were lost between 1972 and 1980. At least some of this decline can be attributed to the availability of inexpensive home appliances that provide an alternative to the rising cost of household labor.

Declining employment in two other occupations can be attributed to two specific technologies. Jobs for telephone operators declined by 76,000 between 1972 and 1980 because of more direct distance dialing, improved switching equipment, and increased use of Central Exchange (CENTREX) telephone systems that do not require operators. Jobs for stenographers declined by 61,000 during this period due to the increased use of dictation equipment.

Technology, through the introduction of new machines and production processes, tends to raise productivity of workers, allowing them to produce more goods or services for the same amount of effort. Yet increased sales of goods or services can actually expand employment even as more capital and less labor is used to produce a given level of output. But in some cases, economic output grows more slowly than productivity, thereby reducing employment. Agriculture best illustrates this case. Economic output from the agricultural sector of the economy has increased steadily throughout this century. Agricultural employment, however, has continued to decline over the same period because productivity in agriculture--due to the increased use of machinery, improved farming techniques, and better strains of crops--has grown at a faster rate. Just between 1972 and 1980, employment for farmers and farm laborers declined by almost 400,000 workers.

The last form of displacement is the most difficult to assess. At least some of the increase in international trade can be attributed to technical developments in transportation and communication. Containerized shipping, for example, has cut loading and unloading time 20 times. The average capacity of ships has also grown, while the

average crew size has fallen from 49 in 1960 to 32 in 1981, reducing costs (Critchlow 1983, p. 229). Innovations in communications, such as satellites, enable firms to keep closer ties with their international operations.

These developments have contributed to a growing worldwide market for goods and services. And they have led to job displacement from both foreign suppliers and foreign operations of U.S. firms.

Foreign suppliers have captured an increased share of the domestic market for a number of goods. Foreign cars now account for more than one-quarter of all domestic car sales (U.S. Bureau of the Census 1982, Table 1058). Imports of foreign-produced goods have also increased more than exports of domestically-produced goods in steel, consumer electronics, and clothing (U.S. Bureau of the Census 1982, Tables 1490 and 1491).

These shifts have reduced employment in a number of manufacturing industries. Shifts in the balance of trade between imports and exports had a negative impact on employment in 21 out of 52 manufacturing industries between 1970 and 1980, although increasing domestic sales offset these losses in many cases (Lawrence 1983, Table A-2). In several industries, however, including leather products, footwear, steel, and motor vehicles, employment declines due to trade reduced total employment over this period. Increased sales of clothing by foreign suppliers, together with improved textile machinery, has reduced employment for textile workers, for instance. Between 1972 and 1980, almost one-quarter million jobs for textile workers were eliminated (Table 1).

Foreign operations by American firms can also eliminate domestic jobs. In some cases this involves the production of goods for foreign markets. Many U.S. companies now produce most of their goods for foreign sale outside the U.S. At least some of this production could take place in the U.S. Several studies conducted during the early 1970s estimated that up to a million domestic jobs were lost due to investment of U.S. firms overseas (Kujawa 1980, pp. 5-15). Since that time, foreign investment by U.S. firms has grown substantially, increasing

from $75 billion in 1970 to $221 billion in 1982 (U.S. Council of Economic Advisors 1984, p. 337). So the loss of domestic jobs has no doubt increased as well, although no recent estimates exist. In other cases American firms produce goods in foreign countries for sale within the United States. Bluestone and Harrison (1982, p. 44) estimate that "twenty-nine percent of all U.S. imports in 1976 came from the output of overseas plants and majority-owned subsidiaries of American multinational corporations."

The movement of production overseas not only arises because of the availability of low-cost foreign labor and improved transportation and communication, but also because of improvements in production techniques. Now foreign workers with little education and training can produce even sophisticated, electronic equipment because of new, automated production techniques. These developments have led a number of American electronics firms to shift production ove[illegible]. In February 1983 Atari announced it was laying off 1700 worke[illegible] in the Silicon Valley of California and moving production to Hong Kong and Taiwan. Since that time, several other electronics companies have laid off American workers in order to move production overseas. These trends are confirmed by a recent report from the U.S. International Trade Commission, which reported that almost one-third of all computer imports in 1980 were actually "re-imports" from American companies located overseas (cited in Pacific Studies Center 1983, p. 2).

In some cases the movement of production overseas is an "invisible" form of displacement. American companies establish or expand foreign plants instead of domestic facilities. In other cases, such as Atari, a domestic plant is shut down and workers laid off in order to move production overseas. The job losses in this case are very visible.

Job Creation

Technology has also created jobs in recent years. Many of these jobs are in computer-related occupations and industries. Between 1972 and 1980, the increased use of computers created 155,000 new jobs for computer programmers, 127,000 new jobs for computer systems analysts,

326,000 new jobs for computer operators. The increased use of a variety of new machines created 256,000 new jobs for health technologists and technicians during this period (Leon 1983, Table 2). The increased sales of computers and other electronic devices also created jobs in industries producing those products. Between 1972 and 1980, employment in office and computer manufacturing increased by 170,000 and employment in electronic components increased by 200,000 (Riche, Hecker, and Burgan 1983, Table 1). Yet these jobs represent only a small fraction of the 15 million new jobs created during this eight year period. Thus this important technology has generated, at least directly, relatively few new jobs in the economy in recent years.

Increased foreign trade and foreign investment have also created domestic jobs. Between 1970 and 1980, employment in several manufacturing industries--engines and turbines, construction and mining machinery, and office and computing equipment--increased substantially because of increased foreign trade (Lawrence 1983, Table A-2). Investment in the United States by foreign firms has also increased during the last decade, creating domestic jobs that have helped to offset the loss of jobs from increased foreign investment by U.S. firms (U.S. Council of Economic Advisors 1984, p. 337). Foreign investment by U.S. firms also creates domestic jobs in the headquarters of these firms and in firms that supply intermediate goods to overseas subsidiaries of U.S. firms (Kujawa 1980).

The Net Impact

Evidence shows that technology has created as well as eliminated jobs in recent years. But what has been the net impact of these changes? No comprehensive estimates exist to answer this question. But several studies have attempted to estimate the net impact of foreign trade and foreign investment.

After examining employment changes due to trade and domestic use in the manufacturing sector of the U.S. economy, Lawrence concludes that shifts in the balance of trade for manufactured goods produced little change in employment between 1970 and 1980. The changing balance of

trade caused employment declines in some industries, and employment increases in others. Overall, however, trade had little influence on employment growth relative to the change in domestic use (Lawrence 1983).

Other studies have estimated the net impact of foreign investment. These estimates vary widely depending on the assumption of how much domestic production could substitute for foreign production. If one assumes that, in the absence of foreign production, U.S. firms would lose sales to foreign competitors, then few domestic jobs are really lost. In fact, there would be a net employment increase due to corporate jobs that remain in the U.S. and due to employment generated in industries that supply U.S. overseas affiliates. If one assumes that domestic workers could produce goods for foreign or domestic sales at competitive prices, then foreign investment decreases domestic employment.

Based on 1970 data, estimates range from a net increase of more than 11,000 jobs in the former case, to a net decrease of almost 2 million jobs (Frank and Freeman 1978, Table 4; Kujawa 1980, Table 1). Because direct foreign investment by U.S. firms has increased by more than $140 billion since 1970 (U.S. Council of Economic Advisors 1984, p. 337), the potential job loss from foreign investment is currently quite sizeable. And although investment in the U.S. by foreign companies has also grown during this period, helping to offset foreign investment by U.S. firms and creating domestic jobs, the difference between the two has still increased during the last decade (U.S. Council of Economic Advisors 1984, p. 337).

Types of Jobs

One concern about technology has to do with the number of jobs displaced. Another concern has to do with the kinds of jobs eliminated. Some believe that technology generally eliminates the most boring and mundane jobs in the economy, freeing individuals for more creative and satisfying jobs. Others believe that technology eliminates many skilled jobs as well. Evidence supports both contentions.

Historically, technology has greatly reduced the need for unskilled physical labor. The vast reduction in the labor requirements of agriculture illustrates the labor-saving impact of technology. Much of the physical labor once required in agriculture is now performed by huge machines, such as combines and tractors. Since the beginning of the century, more than 4 million jobs for farm laborers and foreman have been eliminated in the U.S. economy (U.S. Census 1975, p. 139). Machines have greatly reduced the needs for laborers in other sectors of the economy as well. Over the last 70 years, when economic output and total employment have increased many times, jobs for farm and nonfarm laborers have decreased from 30 percent of total employment to less than 6 percent (U.S. Census 1975, p. 139).

But technology has not only eliminated unskilled jobs. It has also displaced skilled, physical labor. Labor requirements in several skilled and semi-skilled craft areas have been greatly reduced by the use of machines. Between 1960 and 1970, for example, jobs for compositors and typesetters decreased by 29,000 due to the increased use of computer-aided, phototypesetting equipment. During the same period, jobs for machinists declined by 125,000 due to the increased use of numerically-controlled machine tools (Dicesare 1975, Table 2). While technology continued to eliminate unskilled jobs over this period, advances in computers and the increased capabilities of machines allowed displacement of skilled, physical labor as well.

How do the new jobs created in the economy compare to the ones displaced by technology? Are they generally more skilled or less skilled than the ones eliminated?

Unfortunately, there is no easy way to make such a comparison. The reason is that skill levels are difficult to define and to measure. It is particularly difficult to compare the physical skill requirements of a craft job with the mental skill requirements of a professional job (Rumberger 1983). One recent study, based on national data that attempt to measure the training requirements of all jobs in the economy, suggests that the aggregate skill requirements of jobs in the U.S. have changed very little over the last two decades (Rumberger 1981).

Another way to compare the "quality" of jobs is through the use of related measures, such as education and earnings. These measures can be used to compare the quality of jobs that have experienced the greatest reductions in employment with those that have experienced the greatest increases in employment. Table 2 shows the top 5 jobs in each category for the period from 1972 to 1980. The list reveals that the jobs are quite comparable: most have below-average earnings and few require any education beyond high school. In other words, the figures indicate that the jobs being eliminated are generally low-skill and low-wage, but that they are simply being replaced by equally low-wage and low-skill jobs.

Other evidence suggests that industrial shifts in the economy have generated low-wage as well as high-wage jobs. Table 3 shows the average earnings of jobs within major industries in 1980. It also shows the proportion of low-wage jobs--those with annual earnings below $10,000--and the proportion of high-wage jobs--those with annual earnings above $20,000--within each category. In mining, for example, 38 percent of the jobs had high annual earnings, while only 12 percent had low annual earnings. In contrast, 61 percent of the jobs in services paid low wages, and only 14 percent paid high wages.

Comparing the earnings of jobs created between 1960 and 1980 with those that existed in 1960 shows that the two groups are quite similar. Seventeen percent of the jobs in the first group fall into the high-wage category, compared to 20 percent in the latter group; 48 percent of the jobs in the first group fall into the low-wage category compared to 46 percent in the second group. This analysis reveals that the new jobs being created in our economy are quite similar to old jobs: there are high-wage and low-wage jobs in each group and many jobs in the middle.

Other studies suggest that recent job creation has favored low-wage jobs at the expense of middle-wage jobs. An analysis similar to the one above showed that 54 percent of all new jobs created in the service sector between 1960 and 1975 (where most job growth took place) had earnings 20 percent or more below average, compared to 38 percent for all jobs in the economy (Stanback, Jr., 1983, p. 17). A recent BLS study reveals that the average earnings of men in the low end of the

distribution grew more slowly than the earnings of men at the high end of the distribution between 1958 and 1977 (Henle and Ryscavage 1980, p. 9).

This evidence suggests that the new jobs created in the economy over the last two decades were no more skilled than the jobs eliminated by technology. Technology has eliminated both skilled and unskilled jobs. The new jobs created by technology and general economic growth have also been skilled and unskilled. Overall, the distribution of skills or earnings of jobs in the economy have not changed markedly over the last two or three decades.

Future Job Loss from Technology

Technology is likely to have a more severe impact on employment in the future than it did in the past. First, new technologies threaten to displace many more jobs, both skilled and unskilled, in the future. Second, it may be more difficult for the economy to generate enough new jobs because of the continued substitution of capital for labor in production and because of an increasingly competitive world marketplace for goods, services, and labor.

Job Displacement

Future job displacement is likely to be different from past job displacement because the technologies affecting displacement differ greatly. Past technologies, fueled by the development of powerful machines, primarily displaced unskilled, physical labor and, to a lesser extent, skilled labor in some craft areas. But future technologies, fueled by the micro-electronics revolution, will displace mental as well as physical labor at both skilled and unskilled levels. Moreover, this displacement will not be concentrated within particular jobs and industries, as in the past, but will occur throughout the economy.

Recent and expected developments in the capacity, cost, and size of micro-electronics have greatly increased the labor-displacing potential of this technology. Advances in solid-state, micro-electronics

technology have reduced the cost and increased the capacity of silicon "chips" and the computers in which they are housed by many orders of magnitude. By 1975 a $4 micro-processor that could fit on a fingertip had the computational power of an IBM computer that sold for $30,000 in the early 1960s and whose processing unit occupied the space of an office desk (Bylinsky 1980, p. 7). Today a $4,000 micro-computer the size of a small suitcase has the capacity of a $250,000 mainframe computer the size of a small room in 1970. Future developments are likely to reduce the cost and increase the capacity of today's computers several order of magnitudes further.

The small size, high capacity, and low cost of micro-processors and computers have prompted their widespread use and application in the home and the workplace. Cars, home appliances, and most other consumer products are now equipped with micro-processors that can remember a host of preset commands and respond to a variety of conditions. Computers and other sophisticated, micro-electronics devices are transforming work throughout the economy.

In some cases, the increased use of these machines allows workers who use them to perform the work of many other workers. It has been estimated, for example, that a secretary with a word processor can perform the work of two secretaries with electric typewriters (Dowing 1980). In other cases, machines can simply replace workers in particular occupations altogether. Robots, for example, can replace 2 to 3 workers on the assembly line (Howell 1984, p. 9).

Because the field of micro-electronics is changing so rapidly, it is difficult to estimate the displacement impact of particular devices based on this technology. New devices and applications are appearing almost daily. But it is possible to identify particular occupations and classes of jobs that could face displacement from micro-electronics devices. A few of these technologies and the occupations they affect are illustrated in Table 4.

One well-publicized device is the industrial robot. Robots perhaps best illustrate the displacement capabilities of machines because they emulate all the actions of workers: they sense changing physical

conditions, they process this information along with a body of stored knowledge, and they respond accordingly; they can even learn from their experiences. While robots in the U.S. currently number fewer than 3,000, their population could increase to over 100,000 by 1990, eliminating jobs for painters, welders, assemblers, and other operatives. Long-range estimates suggest that robots could replace up to 3 million operatives over the next 20 years and could eliminate as many as 8 million operative positions by the year 2025 (Ayres and Miller 1982, p. 42).

Another labor-displacing development is the automatic teller machine. These machines are now found in banks throughout the U.S. Originally installed to supplement the work of branch banking offices, many banks are now replacing branch offices with newer, more powerful versions of these machines. Bank of America, one of the largest banks in the United States, recently announced it was closing 120 branch offices and eliminating 5,000 jobs in California by consolidating its branch offices and expanding the use of automatic teller machines (San Francisco Chronicle 1983, p. 37).

Labor displacement is also occurring in the engineering field. Drafters are being eliminated by CAD/CAM--computer-aided design and computer-aided manufacturing--equipment. This computer-based device allows engineers to design and redesign any type of large or small product on a computer screen and then have the system produce final working drawings (Gunn 1982). One recent employment forecast predicts that the occupation of drafter could be completely eliminated by the year 2000 (Leontiff and Duchin 1983, p. 4.19).

These three technologies are likely to affect only a limited number of workers in a few selected occupations, at least in the near future. But other technologies, including some that are just beginning to be introduced, could displace millions of workers in the future.

One such technology is office automation equipment--micro-computers that perform a variety of office functions, such as word processing, financial analysis, and filing. A large fraction of the current work force is employed in administrative support occupations--secretaries,

bookkeepers, file clerks--that perform these tasks. But these tasks can now be performed on computers using sophisticated software packages, greatly increasingly the work performed by each office worker. Equitable Life Insurance reduced its staff in one office from 25 to 3 clerical workers by transferring files to computers (Indianapolis Star 1983, p. 26). As these systems become more powerful and easier to use in the future, administrators, engineers, and managers will be able to do this work themselves, with significantly fewer or even no administrative support personnel.

Two other technical developments--debit cards and teleshopping--although still in their infancy, threaten another class of jobs. Debit cards, which look like credit cards, can be used to make direct cash debits from a customer's bank account, eliminating the need for cashiers to handle cash or approve checks and credit cards. Supermarkets and gas stations around the country are now beginning to use these systems (San Jose Mercury 1984, p. C1). Teleshopping, which allows customers to buy goods using a computer, could eliminate jobs for sales workers as well as cashiers.

A final development--computer-aided diagnostic equipment--could greatly reduce jobs for mechanics. As sales of automobiles, computers, and other devices increases, there is an increased need for mechanics to repair these sophisticated machines. But computer-aided diagnosing equipment can now perform one of the two important tasks performed by mechanics--diagnosing machine malfunctions. Sensing devices and computer programs that analyze the data these devices generate allow instantaneous diagnosis of a failed component or other problem. Many computers and other electronic devices can now diagnose their own malfunctions. Mechanics, technicians, or even users themselves simply have to replace a failed part or make a prescribed adjustment.

As computers become more powerful, cheaper, and smaller, new applications will be developed. The more sophisticated the machine, the more sophisticated the mental functions it is able to perform and the greater displacement effect. In the long run, technology will simply continue to reduce the labor requirements of production:

> Computers and robots replace humans in the exercise of mental functions in the same way as mechanical power replaced them in the performance of physical tasks. As time goes on, more and more complex mental functions will be performed by machines. Not unlike large bulldozers assigned to earthmoving jobs that could not possibly have been carried out even by the strongest laborers or draft animals, powerful computers are now performing mental operations that could not possibly be accomplished by human minds. Any worker who now performs his task by following specific instructions can, in principle, be replaced by a machine. That means that the role of humans as the most important factor of production is bound to diminish--in the same way that the role of horses in agricultural production was first diminished and then eliminated by the introduction of tractors (Leontief 1983, pp. 3-4).

Improvements in transportation, communications, and automated production techniques will continue to spur the development of a worldwide marketplace for goods, services, and labor. In order to remain in that market, U.S. producers will have to become more competitive with foreign suppliers. One way to cut costs and to remain competitive is to move production facilities overseas where wages for foreign laborers average about $1 an hour compared to $9 an hour in the United States (San Jose Mercury 1983, p. 1). The continued use of this alternative by firms such as Atari will further eliminate jobs in the U.S.

Another way to produce competitively-priced products is to automate production in U.S. plants. In these so-called flexible manufacturing systems, computer-controlled machine tools produce the parts, robots handle the materials, and computers control the entire production system. These systems allow small quantities of goods to be produced inexpensively and permits rapid changeover to the production of other products. While such factories may keep American manufacturing in the U.S., they are unlikely to provide many new jobs: a showcase Japanese plant employs only one-tenth the workforce of a conventional factory it replaces; a new General Electric plant will produce one locomotive frame a day entirely by machine when it formerly took 70 skilled machine operators 16 days to produce (Blynsky 1983, pp. 57,60).

The continued growth of the world marketplace is likely to increase job displacement, either because foreign suppliers will encroach on the

domestic market or because U.S. firms, in order to remain competitive, will move production facilities overseas or automate production at home. Each of these developments threatens domestic jobs.

Job Creation

Technology will also create jobs in the future. The continued use of computers and other new products will increase employment in firms that manufacture them. And it will increase employment in occupations where people operate and maintain these technical products. But recent employment projections from the U.S. Bureau of Labor Statistics (BLS) suggest that the number of new jobs generated in these areas will actually be quite small.

According to the BLS figures, only 6 percent of the American workforce was employed in electronics and other high-tech firms in 1982 and only 8 percent of the new jobs expected between 1982 and 1995 will be in these industries. Jobs in many computer-related occupations, such as computer service technicians, programmers, and electrical engineers, are expected to increase rapidly in the future. But this rapid growth will actually produce fewer than 1 million new jobs, less than 6 percent of all new jobs expected over this period. The majority of new jobs will be in clerical and service occupations (Rumberger and Levin 1984, Tables 3 and 4).

So technology will create few new jobs in the economy during the next decade, at least directly. The more important issue is whether more jobs will be eliminated by technology than created by technology and general economic growth. One recent forecast suggests that increased technical innovations and their diffusion throughout the economy will lead to a net reduction in aggregate employment. This forecast projected future employment based on three possible scenarios regarding the production and use of robots, word processors, and other computer-based technologies. It was estimated that rapid diffusion of these products throughout the economy could eliminate 20 million jobs by the year 2000, or 11 percent of all the jobs that would exist in the

absence of further technological diffusion beyond 1982 (Leontief and Duchin 1983, Table 1.1).

Two recent studies estimated the net employment impact of one particular technology--robotics. These studies examined only the primary employment effects of robots: the jobs created in the economy where robots are produced and used as well as the jobs created from purchases by robot producers, and the jobs eliminated by the use of robots. Both studies estimated a net reduction in the number of jobs: for every job created, between 3 and 6 jobs will be lost (Hunt and Hunt 1983, pp. x-xi; Howell 1984, p. 15).

This evidence suggests that technology, alone, is unlikely to produce enough jobs to replace those that are eliminated. Whether employment will continue to grow in the future enough to offset the jobs displaced by technology will depend on the general vitality of the overall economy. If the economy can grow at a sufficient rate, it can generate enough jobs to offset those eliminated by technology.

Yet this may become harder in the future than it was in the past. As the costs of labor increase and the costs and capabilities of capital goods, especially computers, decrease, more capital and less labor will be used in the production of the economy's output. And the economy will have to grow by a larger amount to produce each new job.

Recent figures for the manufacturing sector illustrate this trend. Economic output from this sector more than doubled in constant dollars between 1960 and 1980, while employment increased by only 20 percent (Table 5). Part of the increase in economic output can be attributed to an 85 percent increase in the amount of capital per worker. As a result of increased capital investment, each worker produced $10,000 worth of goods in 1960, whereas each worker produced more than $17,000 (in constant dollars) worth of goods in 1980. In other words, manufacturing firms required $8,000 in capital and had to sell $10,000 of goods to create a new job in 1960, while in 1980 they required $14,000 in capital and had to sell $17,000 of goods to create a new job. In the future, the costs of creating each new job and the amount of goods that must be sold to support each worker will continue to increase. The same

dilemma faces other sectors of the economy, where the amount of capital and the value of goods produced per worker has also increased.

What about the quality of the jobs created and destroyed in the future? In the case of robotics, studies suggest that semi-skilled production jobs--operatives, assemblers, welders, and painters--will be replaced with semi-skilled maintenance and clerical jobs--robot technicians, secretaries, and clericals (Howell 1984, Tables 7 and 8).

For the economy as a whole, recent BLS projections suggest that most future job growth will occur in the service sector, where there is a high concentration of low-wage jobs (see Table 3). These figures also reveal that the jobs with the greatest expected employment declines in some cases are much better than the jobs with the greatest expected employment gains. The top five occupations in each group for the period from 1982 to 1995 are illustrated in Table 6. Some of the jobs with large expected decreases, such as private household workers and farm laborers, require little education and pay below-average wages. But others, university faculty in particular, are very good jobs. In contrast, the jobs with the greatest expected increases are clerical, sales, and service occupations that pay below-average wages and generally require no advanced schooling.

These figures suggest that the future economy will not simply eliminate low-skill, low-wage jobs and replace them with high-skill, high-wage jobs. Rather both high-skill and low-skill jobs are likely to be eliminated and created in the near future. In the long-run, however, computer-based machines are likely to displace higher-order mental labor, especially in high-wage jobs, while the continued growth of the service sector is likely to favor low-skill rather than high-skill jobs.

Summary and Conclusions

Technology both destroys jobs and creates them. It is easy to identify particular cases where technology has eliminated jobs and other cases where technology has created jobs. But other employment effects of technology are less visible and therefore more difficult to assess. For instance, technology has facilitated the development of the world

marketplace for goods, services, and labor, contributing to a loss of domestic jobs. Yet technology has also helped to raise productivity and has thus contributed to the growth of the economy and employment.

Th inability to assess the total employment impact of technology, both positive and negative, makes it extremely difficult to provide definitive answers to two fundamental questions about technology: Does technology create more jobs than it destroys? Are the skill levels of the jobs created generally higher than the skill levels of the jobs destroyed? The evidence reviewed in this paper can only supply tentative answers to these questions.

Historical evidence shows that productivity increases have been accompanied by increasing employment, which suggests that, in the past, technology has created more jobs than it has destroyed. But such evidence only shows that past economic growth has been able to produce more jobs than technology has eliminated. Evidence also indicates that past displacement primarily affected unskilled physical labor in limited areas of the economy, primarily agriculture, construction, and mining.

Future job displacement, however, is likely to be more widespread than past displacement and will affect skilled, mental labor as well as skilled and unskilled physical labor. Future displacement will be fueled by the current revolution in micro-electronics that permits computer-based machines to perform higher-order mental tasks. These developments will threaten more and more jobs in the future and will displace workers throughout the economy.

Not only will displacement become more widespread, the economy will have greater difficultly in generating enough new jobs to replace those that are lost. The continued substitution of capital for labor in the production of goods and services will require that the economy grow by a greater amount to produce each new job in the future. And in order to remain competitive in the growing world marketplace, U.S. firms will either have to expand overseas production to take advantage of lower cost labor or automate production at home. Either action is unlikely to provide many new jobs.

It is certain that technology will continue to displace labor in the future. What remains uncertain is whether the economy will grow sufficiently to provide enough new jobs to replace those that are lost and to sustain acceptable levels of unemployment. The time may come when society may have to find alternative means for sharing work and distributing the wealth that it generates (Leontief 1982).

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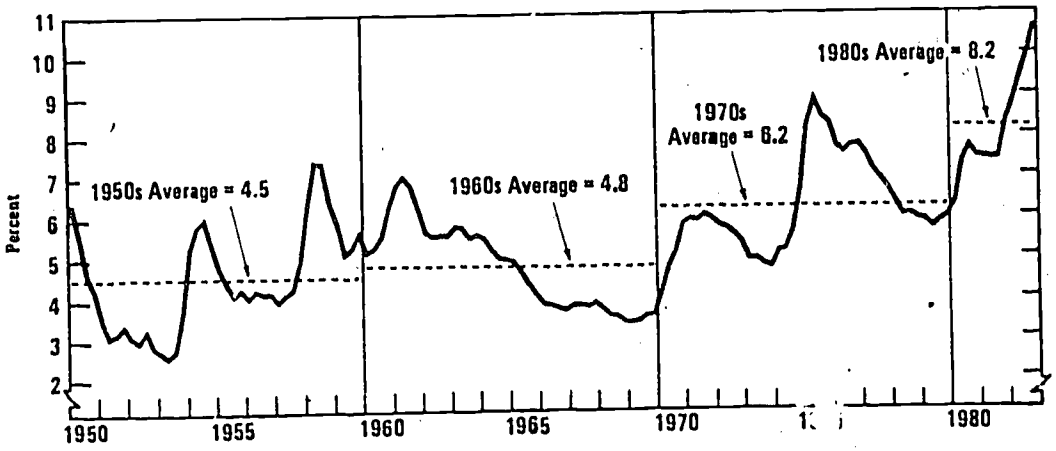
Figure 1

Unemployment Rates for All Workers: 1950 - 1982



Source: U.S. Congressional Budget Office, The Outlook for Economic Recovery, Washington, D.C.: U.S. Government Printing Office, 1983, Figure 25.

Table 1

Employment in Declining Occupations: 1972-1980

(thousands of workers)

	Employment 1972	Employment 1980	Employment Change 1972-80
Delivery and route workers	892	584	-308
Cleaners and servants	713	491	-222
Farm owners and tenants	1,658	1,447	-211
Farm laborers	455	284	-171
Garage workers	502	337	-165
Sewers and stichers	936	788	-148
Child-care workers (private households)	543	431	-112
Textile operatives	424	323	-101
Telephone operators	392	316	- 76
Stenographers	125	64	- 61

Source: Carol Boyd Leon, "Occupational Winners and Losers: Who They Were During 1972-80," Monthly Labor Review 105 (June 1982), Table 3.

Table 2
Employment, Education, and Relative Earnings
for the Greatest Declining and Growing Occupations: 1972-1980

	Employment			Relative Earnings[a]	Modal Education[b]
	1972	1980	1972-80	(percent)	(years)
	(thousands of workers)				
Declining occupations					
Delivery and route workers	892	584	-308	104	12
Cleaners and servants	713	491	-222	28	<12
Farm owners and tenants	1,685	1,447	-211	119	12
Farm laborers	455	284	-171	53	<12
Garage workers	502	337	-165	60	<12
Total	4,220	3,143	-1,077	76	--
Growing occupations					
Secretaries	2,949	3,876	927	67	12
Cashiers	988	1,554	566	49	12
Registered nurses	801	1,302	501	90	13-15
Cooks	866	1,331	465	48	<12
Truck drivers	1,441	1,844	403	117	12
Total	7,045	9,907	2,862	71	--

[a]The average weekly earnings during 1979 of workers in each occupation relative to the average weekly earnings of all workers.
[b]The level of education completed by the majority of workers employed in each occupation in the spring of 1980.

Sources: Employment data from Carol Boyd Leon, "Occupational Winners and Losers: Who They Were During 1972-80," Monthly Labor Review 105 (June 1982), Tables 1 and 3; Education and earnings data calculated from the 1980 Public Use Sample, U.S. Bureau of the Census.

Table 3
Employment and Earnings by Major Industry Group: 1960-1980

	Employment[a]			Earnings[b]			
	1980	1960	1960-80	Mean ($)	Less than $10,000	$10,000-20,000	Greater than $20,000
	(thousands of workers)				(percent distribution)		
Agriculture	2,827	4,685	-1,858	11,813	64	17	19
Mining	1,034	602	432	18,186	12	50	38
Construction	5,189	4,016	1,173	15,350	35	40	25
Manufacturing	21,626	18,539	3,087	14,677	36	39	25
Trans., Comm., Util.	5,631	4,484	1,147	16,520	24	41	35
Trade	19,410	12,181	7,229	10,634	59	27	14
Fin., Ins., R.E.	5,664	2,945	2,719	14,088	49	32	19
Services	18,923	11,043	7,880	11,149	61	25	14
Government	16,730	8,433	8,297	12,377	41	43	16
Total[c]							
1980	97,034			12,919	47	34	19
1960		66,928		13,023	46	34	20
1960-80			33,106	12,651	48	35	17

[a] 1980 employment disaggregated into 1960 employment levels and employment growth from 1960 to 1980.
[b] Total annual earnings.
[c] Mean earnings and distribution among earnings classes for each employment category.

Sources: Calculated from the 1960 and 1980 Public Use Samples, U.S. Bureau of the Census.

Table 4

Potential Displacement from New Technologies

Technology	Occupation Affected	Current Employment[a] (thousands)
Robots	Welders	651
	Painters	130
	Assemblers	1,452
	Other operatives	1,863
	Packers	497
	Laborers	1,000
Automatic teller machines	Bank tellers	516
CAD/CAM	Drafters	335
Debit cards	Cashiers	1,667
Teleshopping	Sales clerks	2,802
Computer diagnostic equipment	Mechanics repairers	3,578
Office automation	Secretaries, stenographers, typists	4,508
	Bookkeepers	1,777

[a]Calculated from 1980 Public Use Sample, U.S. Bureau of the Census.

Table 5
Economic Output, Capital Stock, and Employment
in Manufacturing and the Total Economy: 1960, 1970, 1980

	1960	1970	1980
Manufacturing			
Output (Billions of 1972 $)	171.8	261.2	351.2
Capital Stock (Billions of 1972 $)[a]	140.4	202.2	293.6
Employment (Millions of workers)[b]	16.8	19.4	20.3
Output/Worker (1972 $)	10,226	13,464	17,300
Capital/Worker (1972 $)	8,357	10,423	14,463
Total Economy			
Output (Billions of 1972 $)[c]	732.0	1,077.6	1,449.3
Capital Stock (Billions of 1972 $)[a]	543.2	860.1	1,226.3
Employment (Millions of workers)[d]	65.8	78.7	99.3
Output/Workers (1972 $)	11,125	13,693	14,595
Capital/Worker (1972 $)	8,255	10,929	12,349

[a]Excludes residential capital and government enterprises.
[b]Wage and salary workers only, based on payroll data.
[c]Gross domestic product
[d]All workers, based on population data.

Sources: U.S. Council of Economic Advisors, Economic Report of the President (Washington, D.C.: U.S. Government Printing Office, 1984), Tables B-11, 29, 37; U.S. Bureau of the Census, Statistical Abstract of the United States, 1982-83, 103d Edition (Washington, D.C.: U.S. Government Printing Office, 1982), Table 903.

Table 6
Employment, Education, and Relative Earnings
in the Greatest Declining and Growing Occupations: 1982-1995

	Employment			Relative Earnings[a] (percent)	Modal Education[b] (years)
	1982	1995	1982-95		
	(thousands of workers)				
Declining occupations					
Farm laborers	1,211	1,019	192	53	<12
Private household workers	1,023	850	173	30	<12
College and university faculty	744	632	112	136	17+
Farm owners and tenants	1,407	1,304	103	119	12
Postal service clerks	307	252	55	122	12
Total	4,692	4,057	635	78	—
Growing occupations					
Building custodians	2,828	3,606	778	69	<12
Cashiers	1,570	2,314	744	49	12
Secretaries	2,441	3,161	720	67	12
General clerks, office	2,348	3,044	696	67	12
Sales clerks	2,916	3,601	685	92	12
Total	12,103	15,726	3,623	61	--

[a] The average weekly earnings during 1979 of workers in each occupation relative to the average weekly earnings of all workers.
[b] The level of education completed by the majority of workers employed in each occupation in the spring of 1980.

Sources: Employment data from George T. Silvestri, John M. Lukasiewicz, and Marcus F. Einstein, "Occupational Employment Projections Through 1995," Monthly Labor Review 106 (November 1983), Table 1; Earnings and education data calculated from the 1980 Public Use sample, U.S. Bureau of the Census.