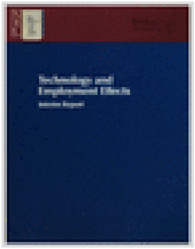

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Technology and Employment Effects

Interim Report

Panel on Technology and Women's Employment
Committee on Women's Employment and Related Social Issues
Commission on Behavioral and Social Sciences and Education
National Research Council

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PREFACE

This report contains two essays commissioned by the Panel on Technology and Women' Employment in conjunction with its study for the Women's Bureau of the U.S. Department of Labor. The panel, an offshoot of the Committee on Women's Employment and Related Social Issues, was established in the spring of 1984 by the Commission on Behavioral and Social Sciences and Education and funded initially by the Women's Bureau and a National Research Council consortium of private foundations and corporations; subsequent sponsors include the National Commission for Employment Policy and the Economic Development Administration. Our charge is to study the likely impact of technological change on women's employment conditions and opportunities.

In initiating its review of changes that have occurred and are likely to occur in the next 10 years, the panel decided that because clerical work is a major source of women's employment, it would focus on the effects of technological change in microelectronics and information processing that are currently transforming clerical work. As background, however, the panel commissioned two review essays about the more general employment effects of technological change in order to provide the context for its study of employment sectors that are especially relevant to women.

The first paper, by H. Allan Hunt and Timothy L. Hunt of the W. E. Upjohn Institute for Employment Research, offers the authors' assessment of the suitability of available national data bases for the study of the effects of technological change on the structure and level of employment. They conclude from their exhaustive review that the available data sources are sorely inadequate, because information on technological change is very difficult to link to information about levels of employment in given occupations and to demographic characteristics of workers. They discuss the ingenuity of some researchers who have attempted to bridge the gap and suggest that some of these research strategies offer possibilities for further development.

The second paper, by Philip Kraft of the University of Massachusetts, reviews selected recent social scientific research reports on the employment effects of several types of technological change. Dr. Kraft concludes that many issues remain open, some of them rather troubling. Current social science research has not provided definitive

AN ASSESSMENT OF DATA SOURCES TO STUDY THE EMPLOYMENT EFFECTS OF TECHNOLOGICAL CHANGE

Timothy L. Hunt and H. Allan Hunt

SUMMARY

The past five years have seen a resurgence of interest in the employment effects of technological change. A careful assessment of the data sources that are available to study the subject is therefore timely, for it is critical to learn everything possible from currently published data. Such a systematic review is also necessary to diagnose what is lacking in the available information. This report compiles information about the major data sources and critically assesses their usefulness in studying the employment impacts of technological change.

The major public and private data bases available to study the employment effects of technological change are described briefly. Information is presented about each, including the agency responsible for the data; the publication(s) in which the data appear; the major characteristics of the data in terms of demographics, geographic areas, and industries; and, finally, special comments about the data. However, it should be emphasized that the focus of the full report is a critical assessment of the existing data from the standpoint of their usefulness in studying the employment effects of technological change. The report also describes what would be an ideal data base for this purpose, reviews selected examples of existing research, discusses the difficulties of forecasting the employment effects of technological change, and offers some conclusions and recommendations. The focus of this summary is on the conclusions and recommendations.

To some degree the essence of change in the way goods and services are produced is the substitution of machines, or capital, for labor. The nature of productive processes tends to be specific to given products; each product tends to require a unique combination of special machinery, labor, and materials. Thus, to study the employment impacts of changes in process technology, one must be able to measure the cost

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Timothy L. Hunt is senior research economist and H. Allan Hunt is manager of research at the W. E. Upjohn Institute for Employment Research. The facts and observations presented in this paper are the sole responsibility of the authors and do not necessarily represent positions of the W. E. Upjohn Institute for Employment Research.

both of machinery and equipment and of labor as inputs to the firms in a particular industry. Since these measures are generally unavailable, it is difficult to study the past or present employment effects of technological change, let alone forecast future impacts.

Office automation and the use of computers in business are not new. The first computer revolution occurred 25 years ago when electronic data processing began to enter our offices and factories. What were the patterns and pace of diffusion of computers in the past? What were the employment effects? How did computers affect the skills required for employment? Clearly, the problems of forecasting the future employment effects of technological change are compounded by our lack of knowledge of such impacts in the past. This in turn reflects the lack of adequate data with which to study the employment effects of technological change.

The central problem is that the data we do have about technology on the one hand and employment on the other are not linked. The existing sources of occupational employment data were developed with particular functions in mind and they do not include any information about the amount or cost of machinery and equipment or changes in technology. There are measures of the demographic characteristics of the work force, but not on a basis that makes it possible to assess the impact of technological change on particular groups. In the area of the technology itself, we lack even the most rudimentary data with which to address policy concerns surrounding innovation, growth, and productivity. Studying the employment effects of technological change with currently available data is like trying to put together a jigsaw puzzle with many of the pieces missing--most of the pieces that are present do not fit together.

The existing federal statistical system was not designed to address this issue. The system is an outgrowth of the administrative requirements of individual agencies or the data needs of the constituent population served by those agencies. It produces reasonably high-quality data that are fairly reliable if used for the purposes originally intended. But this system has led to a patchwork quilt of data sources, and there does not appear to be a strong movement to support the integration of some of the existing data bases. In addition, potential progress on this front has been forestalled by cuts in the federal budget over recent years.

If we are to design conscious policies to prepare for technological change, we must have better information than we have right now. The intense interest over the last few years on the part of policymakers in the employment implications of technological change has not drawn forth a definitive analysis of the problem. In truth it cannot, because the empirical base to support such a definitive analysis does not exist.

New Initiatives in Data Collection

The development of a new, comprehensive data base to study the employment effects of technological change should be given high priority. These data <u>must</u> be collected from the firm; there is no other feasible approach. Establishment-oriented data are critical because all of the data items required can be gathered in a consistent way only at the level of the firm.

We recommend the development of a "Current Establishment Survey" of firms to parallel the Current Population Survey of households. A nationally representative sample of firms representative of the industrial and size distribution of all firms would be surveyed periodically to measure technology in use, investment activity (including changes in technology), employment by occupation (including some demographic characteristics of the workers), raw material inputs, shipments of finished goods, inventory levels, sales, and other variables of interest. In this way inputs and outputs of the productive process could be measured consistently at the appropriate level of observation--the firm. Occupational employment data collected within such a comprehensive framework would be vastly more valuable than currently available data in explaining occupation-employment trends. With careful design and optimum coordination with other existing programs, we believe such a data collection effort would repay the required investment many times over.

Regardless of whether a new, comprehensive establishment-based data source is to be instituted, the development of technological indicators that make it possible to track the diffusion of specific technologies should be undertaken. Such indicators might be based on data such as the number of robots in use by application and industry, the number of computers being applied in different environments, or the type and number of word processors installed. In the not too distant future we might wish to know the number and type of artificial intelligence or voice recognition systems in place, among other emerging technologies. Data for these indicators would have to be collected, though their collection would not necessarily entail the more comprehensive establishment survey discussed above. Direct measurement of the technologies is required to determine specific occupational impacts.

The key to unlocking the black box of technology and employment is to link for the first time selected technological indicators to occupational employment in a systematic way at the level of the firm.

Although more comprehensive data collection is a necessity if we are to gain an adequate understanding of the occupational impacts of technological change, the cost of data collection for the reporting units must be weighed as well. A thorough review of current data collection efforts should be conducted with the intention of improving their overall efficiency. We believe that elimination of some data requests or aggressive consolidation efforts could result in a net decrease in the burden of reporting, even with the new initiatives outlined above. A key principle is that business firms must see the value of the information collection activity. A major share of the resistance to data reporting currently comes from a conviction that nothing useful is ever done with the information tendered. We believe it is essential that the business community be convinced of the usefulness of such information for vital policy purposes. Without their commitment, such a program is not feasible.

Making Better Use of Existing Data

Greater priority must be given to the full use and integration of existing data bases. This approach would improve data effectiveness and not add to the paperwork burden imposed by the federal government on private firms. There are four related tasks. The first involves linking existing data series now collected for disparate purposes. As stated earlier, the existing data bases provide reasonably high-quality data, but they are not adequately linked to each other. The Small Business Administration data base, the development of which is still in process, represents one such attempt to build a relatively thorough data base on the firm or establishment level by combining several currently collected independent series. The more complete the better; much more of this work needs to be done, particularly if a new, integrated data collection effort cannot be developed.

The second task is to continue the development of the Occupational Employment Statistics (OES) program that has been developed by the Bureau of Labor Statistics. The OES system, based on a survey of employers, is the major federal program designed specifically to provide occupational employment data. It was developed in the 1970s in conjunction with the state employment security agencies, and only two complete national OES survey cycles have been completed to date. Its occupation-industry matrix, coupled with estimates of technological change and economic growth, form the basis for its employment projections by occupation (and industry). The OES program may be the leading candidate to supply the foundation for the Current Establishment Survey suggested above. The program has the scope and generality to accommodate the immense quantity of specific data necessary to build a data base that can measure and help illuminate the employment effects of technological change.

The third task involves more effective coordination of case studies and more effective use of their findings. The best empirical work on technological change is that characterized either by intensive mining of available data from a variety of sources or by special fieldwork that yields measures of capital inputs that are more specific to the productive process than are available in national data sets. Frequently this intensive work occurs in case studies of firms or industries because only by restricting the variety of productive processes can sufficient specificity be achieved to yield useful results. But then the generality of the results is limited. It may be that there is no way around this problem. Since the nature of productive processes tends to be specific to given products, there will always be a trade-off between specificity and generality. Accepting the fact that technologies tend to be specific in application, firm or industry case studies may be the most appropriate way to study the employment effects of technological change.

It is therefore critical to develop a way to systematize the results from narrow case studies. The OES program offers some hope in this regard. It creates an occupational-industrial employment matrix that could be used to organize the study of impacts of technology on specific occupations in specific industries. If such an organizational framework guided the design and interpretation of individual case studies, the generality of the results would be increased. At a minimum it would be possible to focus the intelligence gained from each separate case study.

The fourth task in improving our existing data system is establishing priorities across the agencies that produce and use data. How can we update and change definitions yet retain consistency in the data? Can we reduce some of the small differences in data across agencies that render these sources noncomparable? Could data collection efforts of different agencies be combined to reduce the burden on respondents? How can we make more data available to researchers without loss of confidentiality? If there is a social need for integration of the data to study the employment effects of technological change, many of the steps necessary to a plan of action to satisfy that need would also bring other coordination and integration benefits to the current statistical system.

Conclusion

As a society we need to come to grips with the ultimate forecasting questions. How much can we know about the future? How much must we know in order to prepare for the future? We should concentrate our efforts on improving our information where it is most critical and most productive. In our opinion, the impacts of technological change become virtually impossible to anticipate accurately much beyond a 10-year planning horizon. Occupational forecasts based on technological change will accordingly lose some realism beyond that point. We should not squander precious resources trying to forecast the unknowable.

In the long run, technological changes have significantly raised our living standards and improved the quality of life. In the short run, however, some of them have caused disruption of the lives of some individuals and have occasionally led to social conflict. Will this pattern be repeated in the case of the diffusion of recent advances in computer technologies? The truth is that no one knows, but it is possible to gain far better insights into the impacts of technology on employment by improving the data available to study the problem.

INTRODUCTION

The emerging technologies of the 1980s have raised new concerns about the future levels of employment and the structure of work. There is no doubt that the robots being installed in our factories, especially in the auto industry, threaten some highly paid but relatively unskilled positions. Sophisticated word-processing systems are dramatically raising the productivity of secretaries, while linking individual terminals offers the prospect of direct transmission of messages, perhaps bypassing clerical workstations entirely. Indeed, the rapid advances in computer technologies coupled with the new telecommunications capabilities have the potential to change the traditional ways in which we communicate, shop for goods and services, pay our bills, and so on. If these events occur, many occupations in banking, retail trade, and other services will either be transformed or eliminated entirely as more transactions are accomplished through the ever-expanding array of computer terminals.

At the same time that some are raising concerns about the potential loss of jobs, others are speculating about the nature of the new jobs that will be created by these same technologies. Who will maintain the robots in our factories? Who will write the user-friendly software that will be required in the information age? Will these new jobs require dramatic increases in education and training to prepare young people for those jobs? Will we be able to retrain existing workers for these jobs? These are but a small sampling of the many concerns and questions that are being raised about the employment effects of technological change.

Given this resurgence of interest in the employment effects of technological change, it is time to make an assessment of the data sources that are available to study the subject. Clearly, it is critical to glean everything possible from currently published data. Such a review is also necessary to diagnose what is lacking in the available information. The modest purpose of this paper is to compile the major data sources and critically assess their efficacy in studying the employment impacts of technological change.

The paper is divided into three major sections plus an appendix. The purpose of the introduction is to discuss the difficulties of forecasting the employment effects of technological change and to describe the ideal data base to study the subject. The next section then addresses the realities of the available data bases. The discussion includes a review and assessment of the major data sources plus a critique of selected examples of research, emphasizing the data analysis. Conclusions and recommendations are drawn in the final section.

The major data bases available to study the employment effects of technological change are described briefly in the appendix. Information is presented such as the agency responsible for the data, the publication(s) in which the data appear, the major characteristics of the data in terms of demographics, areas, and industries, and finally special comments about the data. Thus the critical assessment of the data is emphasized in the text, and the interested reader can consult the tables in the appendix for a brief sketch of each of the major available data sources. There is also a brief introduction to the appendix that describes some basic concepts as well as the criteria used to include data bases in the tables. The appendix might be especially valuable to those readers unfamiliar with data bases, especially those of the U.S. government.

Dangers in Forecasting the Employment Effects of Technological Change

Technological change is one of the key elements in the dynamic structure of any economic system. It is one of the means through which we grow and prosper. It enables us to produce more goods and services for all of our citizens. Since technological change lies at the heart of economic growth and structural change it is not an easy subject to study. It encompasses the process of change itself, far more challenging than studying stable relationships in the economic system. Technological change is forward looking, an element of instability as we move toward an unknown future. For these reasons, there appear to be certain dangers endemic to studying the subject. The discussion which follows draws much of its tone and inspiration from the ideas of Whitley and Wilson (1982).

The first danger in forecasting the employment effects of technological change is that we tend to exaggerate the revolutionary aspects of any new technology. The automation of our factories is not new; there are few manufacturing industries where the labor share of total cost exceeds 25 percent. Stated bluntly, labor-saving and therefore labor-displacing technology has been and will continue to be installed in our factories. Blue-collar factory jobs have not been a growth occupation since World War II, and total employment in the manufacturing sector has been stagnant for almost 20 years, except, of course, for the vagaries of the business cycle.

It is true that hard automation and hard-wired systems are now giving way to more flexible configurations--soft-wired systems and reprogrammable robots, to name only two examples. But it is surprising how unimpressive an industrial robot is when compared to the maze of other factory automation that surrounds it. Process technology especially tends to be much more evolutionary than revolutionary. This reflects two major facts of life in manufacturing: (1) it must work, and work reliably; (2) it must be cost-effective. These are not characteristic of new technological breakthroughs. It would not be surprising if the primary effect of today's new technology is much like yesterday's technology--to change the structure of work much more than the total quantity of work.

One of the most often repeated arguments to support the contention that microelectronics is truly revolutionary involves the rapid decreases in cost per computation over the last 20 years. No one would dispute the impressive gains that have been realized. But the reduction in cost also leads to increases in the number of applications that are economically feasible. It is simply not true that there is a fixed amount of information to be processed. The silicon chip allows us to dream about processing vastly more information and doing more work, not less. So even if we can do the old amount of work with fewer people, the total number of jobs may still increase.

The second danger in forecasting the employment effects of technological change is excessive optimism about the diffusion of new technologies. It occurred with numerically controlled machine tools in the late 1950s, computers in the early 1960s, and industrial robots in the late 1970s and early 1980s. Utilization of new technologies is not an effortless process. Firms do not scrap all of their capital equipment just because something new becomes available. There are economic constraints on the rates of investment, and there are human constraints on our ability to assimilate new knowledge and put it into practice. Bela Gold, an economist who has studied technological change for over 25 years, concludes (1981:91) that even major technological changes have "fallen far short of their expected effects."

It is natural to be euphoric about the new technologies with which we have had very little experience. This may have occurred recently in the markets for home and small business computers, where many experts have visions of computers in every home and business. Microcomputer manufacturers dramatically increased production in anticipation of the boom. Initial sales gains were impressive and encouraged even further increases in output. The adoption of mass production techniques and competitive pressures contributed to significant price declines, thus fueling more speculation about the potential markets for microcomputers.

The surprise is that in 1984 many of the largest microcomputer manufacturers are reporting lower sales than anticipated. According to one report, the home computer industry is cutting its own sales projections for 1984 by 50 percent ("Expected boom in home computers fails to materialize." New York Times, June 14, 1984). There is even a new study from SRI International that suggests that the long-term growth of the business market for personal computers may be exaggerated (Stanford Research Institute, 1984). These events are all the more surprising because economic growth in 1984 has progressed more rapidly than expected. Apparently, consumers have decided to buy autos, video recorders, and other goods instead of computers. Perhaps both consumers and businesses are unconvinced of the utility of computers in spite of the values attributed to them by the experts. The market for microcomputers might be one illustration of technological capabilities differing significantly from our willingness to use the technology.

The third danger in forecasting the employment effects of technological change is that it is far more difficult to identify the new jobs that will be created in the future by new technology than to identify the jobs that will likely be lost. According to economists, employment is a derived demand, based on the level and composition of the demand for the goods and services that workers produce. The occupational structure and the demand for goods today are known, but not the new goods and new demands that may arise tomorrow. Given some insight about impending productivity-enhancing technological change, we can compile the number of jobs lost using today's occupational data. But tomorrow's events have not yet occurred, so projecting the number of employees that will be needed to produce goods not yet invented is close to impossible.

Since it is so difficult to specifically identify the new jobs that will be gained in the future, analysts generally resort to identifying the reasons to expect increases in the number of jobs. First, there will likely be increased demand for all goods (including goods we have not yet dreamed about) because of higher real incomes and lower costs and prices from use of the new technology. Second, there might be improved performance in the export/import markets. Third, there will likely be increased demand for capital goods both to build and support these new technologies. Finally, there will be long-term multiplier effects as income, consumption, and investment increase in concert. All of these output effects will lead to increased employment in general--more jobs in the economy.

The fourth danger in forecasting the employment effects of technological change is in inappropriately generalizing results from particular case studies. This is a well-known problem of the case-study methodology but particularly acute in assessing the employment effects of technological change. There is a tendency to study showcase installations that may have little in common with other production activities. Even if the new technology studied is deemed to be located in a representative firm, generalizations remain treacherous for many reasons. A researcher may carefully study the activities of a secretarial pool, but not all office typing and filing activities are accomplished in such pools. Indeed, many secretaries outside such pools may spend the bulk of their activities accomplishing other tasks. Robots may perform some painting functions phenomenally well but fail miserably at others. Economists have found that process technologies tend to be unique to a particular industry and not easily transferable to other industries without further research and development. It is therefore difficult to generalize from case studies, no matter how revealing.

The fifth danger is the potential misuse and misunderstanding of data and statistics. Some confusion has occurred recently in understanding the difference between relative and absolute growth rates. A rapidly growing occupation from a very small absolute base will not create very many new jobs. On the other hand, a slow-growing but large (in terms of current employment) occupation may create hundreds of thousands of jobs. This is even more true when occupational replacement needs are considered. This misunderstanding has caused some people to overestimate the importance of high-technology jobs in the future. The truth appears to be that the bulk of our employment will remain in very ordinary jobs for some years to come, despite the rapid growth of jobs in the high-technology sector.

It is important to remember that statistics about occupational employment are aggregations of hundreds of thousands of specific jobs that are actually being done in our economy. Thus, if federal data indicate that there are one million welders in the nation, that does not mean that one million workers are performing welding tasks eight hours per day nor does it say anything about the type of welding tasks that are being accomplished. For example, some have suggested that we no longer should offer welding training since robots and other automated systems are now available to do the work and are being installed in our factories. Undoubtedly it is true that machines are doing more and more welding tasks, but that tells us nothing about the total quantity of welding tasks, nor does it identify the welding tasks that cannot be done by machine. It is by no means obvious that welding is an occupation in danger of extinction.

The final danger in forecasting the employment effects of technological change is that it can strain the limits of what is truly knowable in advance of events. Projection of past trends can provide some guide to the future, but it is not possible to project a trend that has not yet emerged. It is difficult to predict market forces and it is even more difficult to say how market results will change people's behavior. It is not possible to anticipate inventions and technological breakthroughs in any meaningful way, nor have we been very successful in predicting the diffusion of known innovations.

The United States has become a nation engrossed in forecasting the future, and we are pushing forecasters toward longer time horizons and more detail. We wish to know for the next 20 years the probable growth in output by detailed industrial sectors; the new technologies that will appear during the forecast period; the total number, type, and skill level of jobs that will be required in the future by detailed occupational category; and the education and training requirements for those jobs. Of course, all of these forecasts must be precisely time-phased so that we know exactly when to begin our preparations for the future.

It is time for reasonable people to assess the limits of meaningfully projecting future events. Even the ideal data base discussed in the next section will not provide answers to some of the questions being raised today about the course of future events. There are severe limits to our knowledge of the future--especially about technological change and the employment effects that might emanate from such change. Unfortunately, we will have to continue to struggle with inadequate information that, at best, provides only a hazy picture of the future.

Ideal Data Base

It is helpful to describe the ideal data base for studying the employment effects of technological change in order to gain a better perspective about the strengths and weaknesses of the data bases that are actually available. It may also help in identifying and assigning priorities to new data development efforts. The ideal data base is discussed in terms of five dimensions that the data themselves must address: technology, employment, demographic characteristics, geographic detail, and qualitative aspects. Then the necessary statistical properties of the data are presented. Finally, a possible projections supplement to the data base is described, and its role in assessing the employment effects of technological change is discussed.

Since technological change generally involves the substitution of machines or other nonhuman devices for people, it is important that the ideal data base for studying this process have specific content about both populations. If we are to predict the employment effects of technological change, this focus is sharpened even more. It is necessary to have detailed information about the capital equipment being used and about the humans currently employed to provide a firm foundation for any projections of the future.

As far as possible, the measurement of any technology should be direct--number of blast furnaces available, robots installed, numerically controlled machine tool population, computers by type and use, etc. These direct measures should be available both in quantity terms and value terms. The value terms are necessary to relate the direct measures of the technological structure of the industry to the overall industry data on total investment and output. These data should also make it possible to identify what capital equipment (if any) is being discarded or replaced.

Economic research indicates that much of process technology--the technology that is used to produce goods--is unique to a particular industry. Thus, the ideal data base for studying technological change must provide detailed industrial disaggregation. Preferably, the industry classification scheme would be closely aligned to the primary commodities that those industries produce. The goal is to identify industries that are homogeneous in terms of output and thus subject to similar market forces.

The direct measures of the technology and capital investment data provide important insights about the future structure of an industry. But another link is data about research and development in the industry (basic and applied research, product versus process development), including an assessment of the probable impacts of this research. Thus, the ideal data base will provide information about trends in research and development for each industry as well as information about the current changes in technological structure of those industries.

The occupational employment content of the ideal data base is crucial to studying the employment impacts of technological change. The occupations must be detailed and related to the specific technology of the industry. Then it becomes possible to anticipate the occupational effects of installing new technology in that industry. For example, if we know how many production welders are employed in body assembly operations, it is easier to predict the effects of installing automated body-welding systems. We can also differentiate these impacts from those on other welders, perhaps doing specialty welding in a tool and die shop, who will be unaffected by the automated welding systems for body assembly.

At the same time it is also important to have information about the skill levels of those jobs--not the skills of the workers currently <u>doing</u> the jobs but the skills <u>required</u> in the jobs. This will provide important job content information and also help to assess the trends in overall skill levels. It would also help prevent being misled by possible "credential effects" in particular jobs due to labor market conditions. Obviously, these data are valuable to educational institutions and government agencies, especially those involved in planning programs and setting policies for vocational education.

Although occupational employment data are critical to the ideal data base, it is also necessary to have demographic data about the employees currently in those jobs. Such characteristics as age, gender, race, and education of the workers provide important information about the work force. The age data provide clues about likely retirement patterns in the industry and subsequent hiring needs. The gender and race data help us to assess the achievement of our equal opportunity goals by tracking the progress of specific groups in our society. It is also these data that help us determine if technological change will adversely impact specific populations, such as women or minorities. If the demographic characteristics of those affected by technological change are not known, it will be much more difficult to design appropriate intervention or remedial strategies.

Data are also required about various qualitative factors of the workplace. This information may be as important as the quantitative data. Are workers satisfied with their jobs? What are the predominant management structures in industry? What is the nature of labor-management relations? What are the working conditions and how have they been changing? What role does the specific technology used in the industry play in these factors? Studies have shown that the organizational and human aspects of the workplace interact with the technology used to produce output. These subjective data provide important clues about the future of the industry and the entire social system.

In the ideal data base, geographic analysis will be possible at any meaningful level of aggregation--neighborhoods, cities, counties, Standard Metropolitan Statistical Areas (SMSAs), states, and broader regions as necessary. The industrial detail at the regional level should also be the same as that which is available at the national level. Special tabulations would be available on the location of firms and establishments by industry, with special focus on the birth and death of firms in different circumstances. These data would allow the tracking of industry growth and decline by region and improve our understanding of the job creation and destruction processes.

It is also important to have data on a regional basis about the migration of workers. This would help identify developments in regional labor markets. Together with the information about the skills of the work force, it may also suggest training and retraining strategies appropriate to a given region, labor market, or industry. Such a data base would be invaluable in assessing the displaced worker problem and designing retraining efforts.

Another set of major characteristics of the ideal data base are the statistical properties of the data. Some of these have been implied in the discussion of the data themselves, but it is important to identify them explicitly. First, the data must be collected and reported on a consistent time-series basis. That basically means that the definitions of industries and occupations will remain the same, or if changed, the series will be reconstructed with the new definitions. Consistency ensures that meaningful comparisons can be made across time. Without statistical consistency, we do not know if the measured trends and relationships among the data are real or simply an artifact of changes in the definitions.

The ideal data base is a complete census with universal coverage. If sampling is necessary, the data should be benchmarked to census data periodically. When sample data are used, it is vital that they be based on a scientific probability sample with random selection. The resultant sample estimates of the entire universe then are unbiased, with sampling errors that can be calculated. Without random selection, no sound statements can be made about the total population on the basis of sample data.

Other requirements are that the data should be timely and current. Historical observations should be available as necessary. The confidentiality of the respondents and participants must be protected but without degrading the geographic and industrial detail.

The last major aspect of the ideal data base to be discussed is the comprehensive projections supplement. It is a supplement because it is necessary to clearly separate the factual data base from any forecasts. Among other variables, the projections will include labor force estimates by age, race, and sex, with special emphasis on the quantities and likely skill levels of labor market entrants. This labor market information is crucial for educational institutions, human resource planners, and policymakers. The projections will also include estimates of aggregate output, productivity gains, and occupational staffing patterns, all disaggregated by industry. The expected effects of technological change should be easily integrated with these industry forecasts. The projections will use state-of-the-art forecasting techniques.

Users of the projections supplement must be informed about the tentative nature of the estimates because, even with the ideal data base, the projections of the future trends in technological change and other areas will remain treacherous in their uncertainty. For these reasons, the projections must be completely open and assumptions stated explicitly.

In summary, the ideal data base will be comprehensive and fully integrated. Tabulations will be available by industry, by occupation, by area, or by individual characteristics. The data base will have the structure necessary for longitudinal analysis, for following individuals and/or firms over time. This will provide important information about the migration and the location of firms and people. Finally, the data base will have a projections supplement to facilitate forecasting the employment effects of technological change. The projections will be open and assumptions clearly stated to allow for the fact that reasonable people will continue to disagree about the future.

CRITICAL ASSESSMENT OF THE AVAILABLE DATA SOURCES

Currently available data bases bear little resemblance to the ideal data just described. The best occupational employment data do not contain information about skill levels, nor do they really describe the work content of jobs. The Standard Industrial Classification (SIC) system used by the U.S. government to identify industries, even at the most detailed levels, constitutes aggregates of related commodities rather than single commodities. While regional data are available, they are limited in geographic scope, industrial detail, and comprehensiveness. Finally, and most importantly, direct measures of industrial technology are nonexistent except for a few highly specialized cases.

The most overwhelming data problem in studying the employment effects of technological change, however, is the lack of a comprehensive, consistent data base that combines the required measurements in a way that makes it possible to relate cause and effect. There are sources of occupational employment data, but they are developed with particular functions in mind and do not include any information about capital inputs or technology measurements. There is fragmentary information available about the qualitative aspects of worklife, but these cannot be related to any other measures. We have measures of the demographic characteristics of the work force, but not on a basis that makes it possible to assess the impact of technological change on particular groups.

Studying the employment effects of technological change with currently available data is like trying to put together a jigsaw puzzle with many of the pieces missing, so that most of the pieces that are present do not fit together. What is needed is a comprehensive, integrated data base with the multiple dimensions discussed earlier. What is available are unidimensional measures that cannot be related to anything else. Each data source arises in some way out of government regulatory efforts, or was developed for some particular policy purpose. In neither case is it likely that any thought was given to how the information collected might be made to relate to other needs or other programs.

Before proceeding, it is necessary first to review some of the general problems and cautions in using the major data bases available in the United States. This includes the difficulties of comparing household data, establishment data, and that which is constructed from administrative records. It also encompasses the federal confidentiality and disclosure rules. Finally, the question of possible errors in the data is briefly addressed.

Household, Establishment, or Administrative Records

Most existing data are either household-based, establishment-based, or developed from administrative records. The advantage of individual or household data are the virtually boundless possibilities for qualitative content. However, that information is limited to the perceptions of the person being interviewed. The interviewee will probably provide less accurate information about other family members, and the quantitative data will not be precise. It is also likely that interviewees will present themselves and their background in a favorable manner. Thus, when occupational data are requested, a bookkeeper may become an accountant, a technician may become an engineer, a draftsman may become an architect, etc. Survey and interview forms attempt to overcome these problems, but they cannot be eliminated entirely.

Establishment-based data are generally thought to be more accurate quantitatively in part because firms presumably use their proprietary records in completing the survey form. Establishment data are place-of-work data, so employment and payroll are reported for the site or physical location of the plant. This is important to recognize, especially at the regional level, where place of residence and place of work may differ due to commuting patterns.

Given the significant differences in the way in which household and establishment data are obtained, these data series are generally noncomparable, even at the broadest levels of aggregation. A recent article (Stinson, 1984) attempts to reconcile estimates of total U.S. nonagricultural employment from the Current Population Survey, which is a household survey, and the Current Employment Statistics program, which is an establishment-based survey. In the last 3 years the two series have tended to differ by slightly more than 8 percent. Some of the variation is quantifiable and occurs because the nature, scope, and purposes of the surveys differ somewhat. Examples include the treatment of self-employed workers, domestics, agricultural workers, unpaid absenteeism, and others. The bulk of the remaining differences, nearly 3 percent, is thought to be due to multiple jobholders, sampling errors, and other factors. The bottom line is that these differences, quantifiable or not, clearly illustrate how difficult it is to compare household data series with establishment data series even when they purport to measure the same thing.

Data series developed from administrative records are by-products of the agency or program served by those records. For this reason the data are usually highly specialized and sometimes limited in scope and coverage. State agencies collect data on employment and payroll to serve the needs of the unemployment insurance system, but the data are limited to <u>total</u> employment and payroll. The IRS collects a voluminous amount of financial data from individual and corporate taxpayers, but it is limited to the accounting data required to complete tax returns.

Since data from administrative records primarily serve the needs of the collecting agency, there may be significant differences between those records and other primary data series. Furthermore, it is always difficult to assess the importance an agency assigns to verifying and checking the summary statistics that are released publicly as a by-product of their operations.

Federal Confidentiality and Disclosure Rules

Federal and state agencies are forbidden by law to release data that will reveal the identities of individuals or firms. Individual or household data are usually thought to be a lesser problem because social security account numbers and other identifying characteristics can be scrambled while leaving intact the data required for research purposes. However, even for Social Security Administration individual or microdata files and similar files in other federal agencies, concerns about privacy and the cost of constructing specialized data sets may restrict the release of individual data to researchers (Alexander and Jabine, 1978).

The problem of inadvertent disclosure of confidential information has always been more acute for establishment-based data. Disaggregation by industries and areas inevitably leads to small numbers of establishments. The data for a city, county, or state may be withheld because of the limited number of firms or because there is a dominant firm or establishment in the area. This problem increases for more detailed establishment data, such as investment and energy use.

Errors in the Data

Census-based data have a certain appeal because they do attempt to cover the universe of the target population. That does not mean, however, that census data are without error. First, there can be undercounting of the units of interest, perhaps new firms that are not yet registered on the tax rolls or people who prefer not to be counted, such as illegal aliens. Second, there can be various interpretations of the same questions on the survey instrument, or the answers to survey questions may simply be wrongly recorded. Finally, there can be errors due to respondents' reporting the wrong information--willfully or otherwise. Together, all of these are known as nonsampling errors.

Survey-based data are subject to both nonsampling and sampling errors. These latter errors arise whenever the researcher is using a sample from the universe instead of a census. A scientific random-probability sample is used in most surveys to enable the researcher to construct unbiased estimates of universe parameters. The ramdomness of selection is the key to ensuring that the sample estimates are unbiased. It is also necessary to use the laws of probability to estimate probable sampling errors. Contrary to the popular impression, a large sample is not an adequate substitute for randomness.

Realities of Available Data Bases

The purpose of this section is to critically review and evaluate the data bases that are available to study the employment effects of technological change. The focus is on consistent, time-series data bases because they are the most useful in the study of technological change. The data bases reviewed are individually summarized in the appendix of this paper. Readers who are not familiar with a particular series may wish to refer to the appendix when a given data source is first mentioned.

No attempt is made here to be all-inclusive. Since an integrated data base does not exist, the criteria were to include major ongoing time-series data bases that contain information about any one of the critical characteristics of technology, occupations, or demographics. But that also implies that innumerable specialized data bases developed for individual studies have been excluded. For more information about the criteria used to select the data sources, see the appendix. Only those data bases that appear most useful in studying the employment effects of technological change are discussed here. Comments are organized according to the following areas: (1) Technology and Technological Change, (2) Occupational Employment, (3) Demographic Data, and (4) Areas and Industries. Following the general assessment, some particular examples of research on technological change are reviewed to illustrate the way the existing data have been used.

Technology and Technological Change

Direct measures of the technology used in industry are generally unavailable. Private firms may keep records about the technology utilized in their operations, but it is not required recordkeeping for tax accounting or for any other governmental reports. Thus the scattered records of private firms that might be useful in assessing the employment effects of technological change are likely ill-defined, probably incomplete, and certainly inconsistent with the records of other firms. Even so, potential private sources of data that might directly measure some aspects of the technological structure of particular industries were surveyed. These included trade associations, independent research organizations, and others. The results were generally disappointing. The data that are available are fragmentary, inconsistent, and of dubious statistical validity. Some of these data sources are reported in the appendix.

In lieu of direct measures of technology, both the Bureau of Economic Analysis (BEA) and the Bureau of Industrial Economics (BIE) of the U.S. Department of Commerce have constructed capital stock series based on data for investment in structures and machinery and equipment. The BEA series directly supports the national income and product accounts of the United States, while the BIE series supports industrial analysis for 201 3-digit industries. The BIE and BEA data are not strictly consistent with each other, but they are very similar. Both series construct capital stock estimates using the perpetual inventory method (PIM). The basic relationship in the PIM method is

$$K_t = (PI_{t-1})\ I_t + (1-d)\ K_{t-1}\ ,$$

where

K_t = stock of capital in year t
PI_t = price index for investment goods in year t (base = 1.0)
I_t = gross investment in year t
d = constant depreciation rate.

If sufficient historical data are available for investment, the current capital stock can be found by iteration of this equation given some value(s) for the depreciation rate, d. In other words, the capital stock is constructed from the flow of investment less that part of the capital stock that is worn out. The capital stock estimates can be obtained for either the net or gross stocks, as shown by Kendrick and Lee (1976).

Obviously, the determination of the depreciation rate is troublesome because it is not observed directly. One solution is to use tax information, but that suffers from the fact that the tax laws do not reflect true depreciation. A second approach is to use industry surveys, but these are generally not available. The standard approach taken by most economists is to (1) take the Bulletin F service lives published by the Internal Revenue Service about 40 years ago, (2) update those lives by multiplying by some figure less than one to account for the standard belief that service lives today are shorter than those in Bulletin F (BEA chooses .85), and then (3) choose a depreciation method, say, straight-line or double-declining, to finally estimate d.

Regardless of the statistical adequacy of these procedures, there are obvious weaknesses from the standpoint of studying the employment effects of technological change. First, the measures are highly aggregated estimates of structures and machinery and equipment. The components of the capital stock are unknown and unknowable from the current data on investment. Secondly, the PIM method is ill-equipped to handle technological change. For example, the energy crisis may render some forms of capital goods obsolete. Newer capital goods may be very unlike older capital goods because of innovation. But the PIM method treats each unit of investment like those that came before. Such homogeneity denies the very essence of technological change. Nonetheless, the BIE and BEA statistical estimates of the capital stock are the most comprehensive measures available.

Unfortunately, these constructed measures of the capital stock provide no information that would allow us to determine the occupational employment effects of technological change. Moreover, it bears repeating that the newer components of that capital stock may have much different occupational effects than the older capital stock. But only the quantity of investment is estimated, not the quality of the investment in terms of cost reduction or labor-saving potential.

Another source of technology data is the patent counts from the U.S. Patent and Trademark Office. Obviously, patent counts do not measure the value of a patent, whether an industry is using the innovation identified in the patent, or whether an industry will ever use a given patent. It is also true that many industries are not characterized by patenting at all, including much of the fast-growing service sector. Nonetheless, patents remain a gross measure of innovativeness and may signal the speed of technological change in selected industries. An example of research that uses patent counts to measure innovation is described later.

Another vein of data about technology comes from the National Science Foundation. NSF provides various series on research and development spending in private industry, as well as data about the employment of scientists and engineers. The employment of scientists and engineers is generally taken as another surrogate for innovativeness, or the relative importance of research and development to an industry. The research and development spending data do not appear to be disaggregated sufficiently to have more than limited usefulness in studies of the employment effects of technological change. Furthermore, the links between doing R&D and applying R&D are not clear-cut.

In summary, the best national sources of data on the technological structure of American industry are grossly inadequate to study the employment effects of technological change. And, for the most part, the private sources on specific technologies are either nonexistent, fragmentary, or of dubious statistical validity.

Occupational Employment

The second critical link in studying the employment effects of technological change is data on employment by occupation. It is surprising, however, how many data sources provide information only about aggregate employment. For instance, the economic census of manufactures provides data on employment but disaggregated only into the broad categories of production and nonproduction workers. County Business Patterns (CBP) data provide a wealth of information about total regional employment by industry but absolutely no data about occupations. This reflects the stated purposes of the data bases but it also indicates the lack of priority given to the development of occupational data by the federal government, at least until the last decade or so. The two primary sources of occupational data today are the Occupational Employment Statistics (OES) program and the Current Population Survey (CPS). Broad occupational groupings are available from the EEO-1 files, but the discussion of that data is deferred until the next section, which addresses the demographic characteristics of available data bases.

The OES data base evolved in the 1970s as a cooperative effort of the Bureau of Labor Statistics (BLS) and the state employment security agencies to make career guidance information available to educators, guidance personnel, human resource planners, students, and other interested parties. It is based on a survey of nonagricultural employers. All three-digit SIC industries are grouped into one of three primary areas. Each of the three primary areas is sampled on a rotating schedule every three years. Thus, for instance, the individual three-digit manufacturing industries were sampled in 1977, 1980, and 1983--similarly for the other two sectors. Periodically the BLS pulls all these data together into a national occupational-industrial matrix; the most recent one was for 1982.

The OES system includes tabulations of nearly 1,700 occupations. The emphasis is on ease of administration, so the occupational classification system reflects employers' use of job titles. This means that there is actually less detail available than is implied by the 1,700 occupational titles in the OES system. A large number of the titles are actually quite specific to a particular industry or sector. According to the most recent OES data, there are almost 1,000 OES occupations with 5,000 or fewer employees nationwide. The occupational definitions were developed prior to those in the Standard Occupational Classification (SOC) system of the U.S. Department of Commerce. Thus, BLS, like other federal agencies, has tried to make its definitions consistent with the SOC. A crosswalk is available from the OES definitions to those in the SOC.

Employers are surveyed using either a short or a long form; the short form is used for smaller establishments to reduce the reporting burden on those firms. The long form lists no more than 200 occupations for each firm, although firms are encouraged to list new occupations and to provide definitions for those occupations. The sample of establishments is stratified by industry and size class, but all establishments with 250 or more employees are included with certainty.

The OES data base provides the most detailed data available about occupational employment in the United States. However, it is oriented to job title and does not really provide much skill level information. The Dictionary of Occupational Titles (DOT) (Employment and Training Administration, 1977), which does provide this general type of information, lists over 12,000 specific occupations by work level. While the DOT covers an impressive array of occupations, it includes no information at all on employment levels for those occupations. It was developed as an occupational guidance tool for use in the employment service offices to match unemployed workers with possible occupational opportunities. The emphasis is on the requirements for entry into the occupation, not on the number of people employed in the occupation.

In general, there are trade-offs between the specificity of the occupational categories, the skill levels reflected in those occupations, and the cost to collect the data. As the number of occupations increases, the definitions for those occupations will become narrower and will more adequately convey skill levels. Clearly the occupational category of professional and scientific workers is less informative about skill requirements than that of chemical engineers. At the same time it should also be obvious that costs may increase dramatically as the detail of occupational information increases. It also adds to the reporting burden on firms or households where the data are collected.

The OES system is used primarily as a data base for BLS employment projections by occupation. The occupational employment projections for the United States in 1995 were released late in 1983. The 1995 projections for manufacturing utilize the OES survey results from 1980 and industry employment figures for 1982 as a baseline. It is instructive to examine the OES forecasting system in more detail for the insight it offers into the complexity of occupational forecasting.

The OES forecasting system is actually a group of separate projections that are linked to each other for consistency. Aggregate economy-wide activity is forecast first. This includes, among other variables, labor force projections by age, race, and sex, and aggregate output decomposed into its major components. Due to BLS budget constraints and the large amount of staff time necessary to maintain an aggregate econometric model, the most recent aggregate forecasts were purchased from Chase Econometrics, Inc.

The second step in the OES forecasting system is to develop industry output projections that are consistent with the aggregate output projections of step one. The 156-sector input-output (I/O) model, prepared by the Bureau of Economic Analysis, U.S. Department of Commerce, is used for this purpose. Given a set of industry demand figures, the I/O model can calculate the total industrial production required to meet those demands. The I/O system utilizes "bridge tables" to allow for anticipated shifts in demand for inputs and outputs.

Once the industry output projections are determined, productivity gains are forecast to arrive at industry employment. The productivity gains are estimated separately for each industry, with an econometric equation. Worker-hours are estimated as a function of the industry's output, capacity utilization, relative price of labor, and--as a proxy for technology--the output/capital ratio. The implication of the technology proxy is that more capital per unit of output implies the need for fewer worker-hours. Finally, the estimates of total worker-hours are combined with other estimates of average annual hours per person to arrive at the industry employment levels.

The last step in the OES projections system is to forecast occupational employment within these industry levels. The basis for these projections are the occupational staffing patterns from the latest OES surveys. The individual occupational coefficients are adjusted on a judgmental basis to account for the changes in occupational demand anticipated as a result of technological change or other reasons. For example, computer-related occupations will likely become relatively more important in many industries as computers are more widely applied in those industries, so the coefficients for these occupations are increased correspondingly. These revised staffing coefficients are then applied to the previously forecast level of industry total employment. The sum of the occupational employment across all industries, then, becomes the new occupational projection of BLS.

Several features of the OES system should be noted, particularly those that relate to technological change. Technological change actually enters the system in at least three places. First, the industry output projections should account for anticipated changes in demand induced by technological change. Second, the estimated productivity gains forecast for each industry should be influenced by technological change. Finally, the staffing patterns themselves are altered directly to account for technological change. In other words, technological change will have specific effects on some occupations, it will have an overall impact on the productivity of workers, and it will affect the demand for goods and services generally.

It is worthy of note that this system involves a considerable amount of judgment, especially in anticipating the effects of technological change. There are no simple equations that predict changes in staffing patterns within an industry. In fact, the BLS staff has found that trends in industry employment levels can be predicted more accurately than the changes in occupational employment (Office of Economic Growth and Employment Projections, 1981). This is due in large part to the difficulty of projecting specific occupational impacts of technological change.

The Current Population Survey (CPS) is the second major source of occupational data in the United States. However, the main function of the CPS is to provide reliable monthly estimates of employment and unemployment. It is a random survey of about 60,000 households each month. The March supplement to the survey includes detailed questions about occupation, work experience, multiple job holding, educational status of workers, etc. The sampling strategy is carefully developed to ensure the accuracy and quality of the monthly unemployment estimates. The CPS appears attractive for the study of the employment effects of technological change, but there are limitations to this data source.

First, the sample size is not sufficient to provide detailed estimates by industry and occupation. The CPS now uses the coding scheme of the Bureau of the Census, as published in the 1980 Census of Population: Classification Index of Industries and Occupations (Bureau of the Census, 1982). That system consists of about 500 occupations and 231 industries--the number of industry-occupation cells is nearly double the number of households sampled. For these reasons, industries are aggregated into broad groupings for publication. The detailed occupational data are published separately as occupational totals without indicating the industry of employment.

The second problem with the CPS for occupational analysis is that the data are not always consistent or comparable across time. The 1980 census classification was actually adopted for the CPS in January 1983. The new classification system is based on the Standard Occupational Classification (SOC) system, mandated by the Office of Federal Statistical Policy and Standards in 1977. It represents a movement toward standardization of occupational definitions, but there is no linkage to the earlier CPS occupational system based on the 1970 census classification scheme. Furthermore, the changes in concepts and definitions are significant, even for some major occupational groupings.

BLS has attempted to bridge this gap in the data (Klein, 1984). They developed conversion factors for the old and new series based on six months of overlap data in 1981-82; this was in lieu of direct recoding since funding was not available to accomplish the laborious task of analyzing individual CPS records. The statistical estimation procedure utilized by BLS was judged reliable enough to produce annual estimates only for the period 1972-1982. However, that reliability did not extend to the detailed occupations, but only to the major occupational groupings.

In addition, there are the old questions about the reliability of the occupational information gathered from household surveys, including the decennial census. Such data are susceptible to reporting bias, as each respondent may be prone to inflating occupational status. There is the problem of second-party reporting of occupational information, which is a characteristic of household surveys. There is also some question of whether a survey designed principally to measure the number of unemployed persons can adequately serve the goal of measuring occupation among those who are employed. For these reasons, among others, the BLS decided to develop the separate, employer-based OES survey described earlier.

In summary, the CPS is a major source of occupational data but it must be used cautiously. It cannot provide detailed industry-occupation estimates. Rather, it provides estimates of occupational <u>or</u> industry employment. Clearly, experience has taught us that both are required when studying the employment effects of technological change. Furthermore, the break in the historical series in 1983 is so great that comparisons with earlier estimates are not valid, except for major occupational groupings. Thus, the series is not available on the consistent time-series basis needed for tracking the effects of technological change.

A third source of occupational data is the decennial census of population itself. A census has the considerable advantage of full representation of all the occupational, industrial, geographical, and demographic information desired, limited only by the difficulty and expense of collecting, tabulating, and reporting it. Clearly, the decennial census could become a more valuable tool in tracking technological impacts on employment patterns over long periods of time. But since it includes no information whatsoever about the technology itself, it is only half the story. To become really useful, the census of population would have to be linked to a data base on firms and establishments so that changes in technology could be linked to changes in individual situations.

It is also clear that 10-year intervals are not sufficient to capture the details of changes that are occurring as a result of technological change or other factors. The period of observation would have to be more frequent to make these data really valuable for forecasting the employment effects of technological change.

There is also the problem of consistency of measurement across such long periods of time. The problem of the 1980 revisions in occupational codes was discussed above. It should not be inferred from this discussion that the changes in occupational definitions have been arbitrary or capricious, or that federal statistical practitioners are misguided. Indeed, the SOC resulted from the pressures inside and outside of government for some standardization, and the 1980 census classification system does represent emerging occupations in such fields as computers much better than the 1970 system.

Even though both the OES and CPS are now nominally based on the SOC, this does not mean that these two sources of occupational data are statistically compatible either. What it does mean is that researchers can perform a complicated crosswalk between the two systems using the SOC as the bridge. However, the differences between classification systems of 500 and 1,700 occupations are enormous. We know of no analyses of the adequacy of the crosswalk but cannot recommend comparing <u>numerical</u> estimates of employment. The crosswalk is better reserved for trainers or guidance counselors who wish to know the relationship between an OES or CPS occupation and the detailed listings in the DOT.

There are a few other data sources that address labor market information but are of lesser current significance than those already mentioned. First is the data base that arises out of the administrative needs of the federal unemployment insurance system. The Employment and Wages Program of the BLS (commonly called the ES-202 program) yields detailed information for nearly every employer in the nation on total employment and total payrolls on a quarterly basis. This data source is probably underutilized, in part because of the confidentiality problems that arise when smaller regions or areas are the unit of analysis. Unfortunately, these data do not include any information whatever about occupations.

A related data source is the Current Employment Statistics (CES) program, commonly called the 790 program. This is a monthly survey of employment, payroll, and hours of work for nonsupervisory, production, and construction workers. Limited data are published by gender, but there is no occupational content. These data, published in Employment and Earnings, are one of the longest time-series data sets on employment extant anywhere. Unfortunately, they cannot contribute to an analysis of the specific employment effects of technological change beyond measuring industry employment levels.

Two other BLS programs are also noteworthy: the Industry Wage Survey and the Area Wage Survey. In each case the goal is to provide data on occupational compensation levels; in one case by industry and in the other by geographic location. These sources are useful in giving rough indications of labor market results for various common occupations. Unfortunately, while there is some occupational employment detail in these surveys, the surveys are not based on random probability sampling procedures; it is thus impossible to make population estimates from the sample data.

Before proceeding, it may be best to summarize the discussion of the occupational data that are available as measured against the ideal data base. First, there are no detailed, consistent occupational data over a substantial period of time. The best data are those from OES, which are based on surveys of each industry once every three years. Second, none of the available quantitative occupational data relate very well to skill levels, actual work responsibilities, or to the multitude of job definitions used by private industry. Once again, the most detailed source of occupational data, the OES, is an aggregation of the thousands and thousands of job titles that are used by employers in the U.S. economy. Third, there is currently no way of linking the OES occupational employment data collected from the firm to the necessary information about the technology in use by the firm or to other critical elements of firm structure. Thus it is only half the story.

To illustrate this problem: It is impossible to relate the employment of welders and flamecutters to the circumstances that exist for that occupation in a specific firm or a specific industry. It is not known what the welders are actually working on or how they fit into the overall organization. For example, if they are working in maintenance and repair the impact of technological change will be quite different from that experienced if they are working in direct production activities. The OES occupational data base that is in place in the United States is an excellent skeletal structure but it needs further development. These matters will be discussed again later in the paper.

Demographic Data

Demographic data frequently are collected in a way that makes it artificial to discuss them independently of employment data, but it is convenient to treat these issues separately. For the sake of brevity demographic characteristics considered are restricted to age, gender, race, and education. It is interesting to note that the major source of occupational data, the OES, contains no demographic information. This can be taken as a general attribute of data that are collected from employers rather than from individuals.

In this section the CPS is examined as a source of demographic data; the EEO-1 files and the specialized data from the National Science Foundation on science and engineering personnel are also discussed. We begin, however, with some thoughts on the possible role that these data might play in assessing the employment effects of technological change.

Technological change might appear to be neutral vis-à-vis different demographic groups but it can and does have impact on specific occupations. As we are all very keenly aware, jobs are not distributed randomly among individuals, without regard to their age, gender, race, or educational level. Discrimination is a factor in labor markets and in labor market outcomes. But if technological change has the power to influence the demand for particular types of labor, then specific age-gender-race groups can be affected disproportionately. The value of demographic data in studying the employment effects of technological change is that it allows one to identify these differential impacts.

It is important that equal opportunity goals not be subverted by other goals that might be adopted. If we were to adopt a national policy goal of more rapid technological change, for instance, it would be vital to be able to discuss the impact particular policies might have on other goals. We cannot reach rational compromises between different policy goals without an adequate understanding of how they may conflict with or reinforce each other. Clearly, this is another strong reason for studying the demographic aspects of the employment effects of technological change.

Besides providing occupational data, the CPS also provides demographic data. Once again, the detail is limited somewhat by the size of the sample. In terms of the detailed occupations, data are published by gender and race (caucasian, black, and other). For broader aggregations of occupational groupings additional data are available. However, the 1983 revision of the CPS and the switch to the 1980 census occupations create a break in the occupational data by gender and race. In fact, according to the BLS, the conversion factors, even for the broad occupational groupings, were not judged to be reliable for age and racial groups (Klein, 1984). Thus, consistent time-series data are available only from 1972 to the present by broad occupational groups and gender from the CPS.

Six separate data files are maintained by the Equal Employment Opportunity Commission to assess compliance with the nation's equal opportunity laws. The files pertain to private employers, apprenticeship, unions, education, and state and local government. But the data base on private employers, or EEO-1 file, appears to have the most potential for studying the employment effects of technological change. The EEO-1 reports have been required since 1966 of all private employers with 100 or more employees. Special procedures apply to federal contractors and to employers in Hawaii due to the unique racial and ethnic composition of the population in that state. Multiestablishment employers must report separate employment data for the headquarters unit and for all establishments with 50 or more employees (25 employees for most years prior to 1983). Considerable detail is available for three-digit industries, a variety of geographic areas, and nine broad occupational groupings, subject to confidentiality requirements.

The strength of the EEO-1 data derives from the purpose of the survey itself--to provide data on employment by gender and minority status. Separate data are shown for each of four minority groups: Blacks, Hispanics, Asian Americans, and American Indians. In fact, it is one of the few data sets with information about Asian-Americans and American Indians. The demographic detail in the EEO-1 files may be the best that is available for race and gender, cross-classified by occupation and industry. The data are also on a continuous time-series basis (annual) and relatively current (1983 data are available). It is noteworthy that the definitions of the nine broad occupations have remained unchanged since the inception of the survey.

Although the EEO-1 data have significant potential for assessing the employment effects of technological change there are some limitations in the data as well. First, the EEO-1 surveys are a virtual census of private employers with 100 or more employees. But that also implies that coverage of the survey varies substantially across industries. Specifically, the EEO-1 files are less comprehensive for those industries characterized by large numbers of small employers and/or small establishments. Coverage generally ranges from 30 percent in trade and services to 70 percent in manufacturing, transportation, communication, and public utilities, although it can be very low in a few cases like agriculture and construction. In comparison with the BLS data from the CES program, overall EEO-1 nonagricultural coverage is about 45 percent.

Second, the EEO-1 survey is obviously not random nor does it pretend to be a scientific probability sample, i.e., universe estimates are not published. To some degree the EEO-1 data may be more appropriately regarded as a large-firm data base, where the primary sampling units move in and out of the sampling frame depending on the level of their employment. That characteristic is not a desirable statistical property because the excluded population of small firms may be significantly different from large firms. Of course, a sample of smaller firms would have the potential of remedying this flaw.

In summary, the EEO-1 data have potential in the study of the employment effects of technological change, but the occupational groupings are quite broad. The statistical properties of the sample are uncertain since firms move in and out of the survey depending on employment. And, of course, there is no linkage to other establishment data that relate to the technology in use by the firm or plant.

Another data base that appears to have significant potential in terms of its demographic content is the specialized data maintained by the National Science Foundation (NSF) on scientific, engineering, and technical personnel. Considerable data are available by gender and race. The racial groups are generally defined as white, black, Asian, Native American, and Hispanic, although breakdowns vary depending on the particular series. Among other activities, NSF surveys recent graduates in science and engineering. It also utilizes the Doctorate Records File of the National Academy of Sciences (a virtual census of individuals holding doctorates in the United States in all fields) to survey highly skilled, experienced workers in science and engineering fields on a routine but infrequent basis.

The NSF data provide a specialized source very rich in detail within the technical fields. The surveys explore qualitative questions about the work experience as well as quantitative questions about employment, salaries, etc. The use of this data source to study the employment effects of technological change may be limited but it deserves consideration.

Another massive data source for demographic information that is only of limited use for the purposes at hand is the Social Security Administration's Continuous Work History Sample. This sample of individual employment records allows analysis of earnings levels and duration of employment by age, race, and sex. By reference to the location and/or industry of the employer, additional detail can be garnered. However, there is no information about occupation, and employment coverage is not universal due to Social Security Act exemptions for certain types of employers. It is possible to track the earnings and employment history of particular demographic groups; it is just not possible to relate the results either to technological change or to the occupation of the individuals.

The National Longitudinal Surveys of Labor Market Experience (NLS) should be mentioned here as well. While this is not a regular time-series data collection program, the NLS, conducted by the Center for Human Resource Research at Ohio State University since 1966, is a unique and rich data base. It is longitudinal in design, so the emphasis is on tracking particular individual respondents across many years of labor market experience. Occupational and industry information is gathered, as is a wealth of demographic detail. There is also qualitative information about the work environment in the NLS. However, the samples are quite small and are targeted on particular demographic groups, particularly older men and women, youth, and minorities. While these data are excellent for assessing progress in the labor market of particular groups of people, they are not well adapted to studying the employment effects of technological change. There is no way of knowing whether the experiences of such a target group are representative of the working population as a whole when looking for the impact of technology. Still, these data can be indicative of trends for the wider population.

Another similar effort is the Panel Study of Income Dynamics (PSID), conducted by the Institute for Social Research at the University of Michigan. The primary thrust of the PSID is the well-being of low-income families. Thus, unlike most other data collection efforts, the basic unit of observation is the family rather than the individual.

Again, there is very rich detail on the demographic characteristics of the sample, and occupational information is generously collected as well (including detailed work histories). But there is really no way to relate the labor market experiences of the sample to the broader society, and the sample sizes are too small to permit much disaggregation by occupation or industry.

In general, the available demographic data are rich and varied but not well integrated with the major sources of occupational and industrial data. The EEO-1 and the NSF data offer the greatest opportunities for future research. They will be discussed again later in the paper.

Areas and Industries

Many data sources have both a regional and industrial dimension. Since there appears to be increasing demand for regional and industrial detail, this type of information has been included for the data sources listed in the appendix. Specifically for each data source the availability of the data by areas and industries has been highlighted. A brief introduction to the Standard Industrial Classification (SIC) system is also provided in the appendix for those readers unfamiliar with the assignment and meaning of SIC codes at various levels of industrial aggregation.

Although considerable data exist by areas and industries, it is difficult to construct statistical interrelationships. First, federal guarantees of confidentiality prevent disclosure of data as the area and industrial detail increases. It is virtually impossible to study any U.S. industry by area and keep the property that the area data aggregate to the U.S. totals for that industry. This incompleteness of the data is sometimes further complicated by omitted data elements, where specific information for a given year has been suppressed to prevent disclosure of individual firm data. This occurs especially in detailed series such as those on investment, energy use, etc.

Second, the comparability of the area data is limited because so much of the data is developed as a by-product of administrative records. Since those data primarily serve the needs of the agency, they tend to be limited to specific items of interest defined by the agency, thus contributing to a lack of comprehensiveness. The Social Security Administration records obviously are limited to those workers who participate in the program; likewise for the unemployment insurance program, etc. The net result is a hodgepodge of area and industry measures that differ in coverage, definition, and data items.

Another factor that may affect the comparability of data from administrative records is that some of the data is collected from the state agencies responsible for those programs. The federal government is not in a position to verify the submissions of the state agencies, so quality control could be a problem. Unfortunately, state agencies have been operating under extreme budgetary pressures, so it is probably unreasonable to think that data verification, coding, and statistical aggregation are high-priority tasks. Thus the quality of the area and industry data from administrative records is unknown. It may vary within data bases due to differing priorities assigned to the task by the states and it may vary across the data bases.

It should be emphasized that statistical errors and other noncomparabilities in the data become greater problems in establishing statistical interrelations for smaller regions. An extremely small error in the U.S. total for some variable may constitute a large and significant component of the regional value for that variable. Sometimes even standard rounding procedures can make detailed area and industry data virtually useless for analysis. For instance, the dollar value of variables are frequently rounded to millions of dollars, or the number of workers may be rounded to the nearest thousand. But for a small area or industry the total may be only a few million dollars or a few thousand workers. Thus the rounding effect can introduce a significant distortion to the total figure.

The third reason that it is difficult to construct statistical interrelationships with area and industry data is that the industries identified in the SIC system produce similar or related products rather than single commodities, even at the detailed four-digit level of industrial disaggregation. For instance, about 60 products are included in SIC code 3634, Electric Housewares and Fans. These include electric blankets, food mixers, portable electric ovens, and electric razors, to name only a few. These products may be similar (electric housewares) but it is difficult to defend the notion that the production processes that create electric blankets are the same as those that create electric razors. Thus one cannot be at all confident that the application of new technology in the production of razors has any implications whatsoever for the production of electric blankets, albeit the identical SIC codes.

Finally, before proceeding to a discussion of the major area and industry data sources themselves, it should be mentioned that the cost of improving these data bases is a major impediment. Given an acceptable statistical precision level, the cost of collecting area and industry data is nearly proportional to the number of areas and industries desired. Indeed, one of the advantages of using administrative records to develop area and industry data is the cost efficiencies achieved in the process. The price of those cost efficiencies is a fragmented area and industry data base that is far less comprehensive and comparable than national aggregate series.

The primary source of detailed industrial data for areas and industries are the economic census of manufactures and the annual survey of manufactures. Subject to federal disclosure rules, data are available on a multitude of individual data items such as investment, inventories, materials usage, energy usage, etc. But the employment data are reported only for production and nonproduction workers, so the occupational content is virtually nil. Furthermore, the definitions of the industries and areas may change, so some particular series may not be comparable over time. Each of these matters will be discussed in turn.

The definitions of industries in the SIC system generally undergo revision every economic census (five-year intervals). The 1972 revision was particularly significant, while the 1977 revision was relatively minor. The purpose of these revisions is to more adequately reflect the current industrial structure of the United States. The cost, however, is that it creates a break in the data over time. For instance, the 1972 economic census data at the two-digit level cannot be compared with the data for 1967 because of substantial changes in some of the three- and four-digit groupings; nor did the Bureau of the Census reconstruct the earlier data with the new definitions (Vaughan, 1977:142). Unfortunately, it is becoming more common for federal agencies not to reconstruct historical data when new definitions are adopted because of severe budget limitations. Thus researchers must be extremely cautious in using any time-series data. Occasionally, major series are benchmarked to new definitions or procedures; however, that is less likely as data are disaggregated industrially or regionally.

Special note should be made of the changing spatial coverage of Standard Metropolitan Statistical Areas (SMSAs). SMSAs are defined as integrated economic and social units where the central city has at least 50,000 population and the outlying areas, generally counties, are tied to the city by the dominant commuting patterns. Researchers have focused on SMSAs because this emphasis on economic integration constitutes a better unit of measure for regional analysis in many cases than legal boundaries.

However, the SMSAs are redefined periodically, generally after each decennial census of population, to account for changes in the population of cities and in commuting patterns. Thus, counties may be added to or deleted from SMSAs as commuting patterns change, rendering the time-series data noncomparable. It should also be mentioned that the level of disaggregation of SMSA data varies widely, so it is difficult to construct spatial series in any case.

One other problem with the economic censuses is that the data for areas and industries are not published on a timely basis. For instance, the annual survey of manufactures is complete only through 1978, and nothing but the most aggregated series are available so far from the 1982 Census of Manufactures. It is not unusual for economic census data to be available only after a lag of three to five years. Thus the economic census data appear to have impaired value to researchers who wish to study the employment effects of technological change.

The second primary source of area and industry data is the County Business Patterns (CBP) program. The CBP data provide estimates of total employment, total payroll, and the number of establishments. The detail of the data series is limited in the CBP, at least compared to the economic census of manufactures. However, CBP data are more timely, available through 1982 currently, and they do provide disaggregated data for counties and four-digit industries, subject to federal disclosure rules, of course.

The source of the CBP data are various administrative records from the Internal Revenue Service, Social Security Administration, and others. The program also relies on the annual company organization survey of multiestablishment firms. The employment estimates parallel those from other programs such as the unemployment insurance program, but the data are not directly comparable. Given the lack of occupational content and the lack of industrial data on outputs, the possibilities of using CBP data to study the employment effects of technological change appear remote. Still, the CBP data have been and probably will continue to be the starting point for many area and industry research studies.

Another data base, newly developed, which has potential for industry and area analysis, is that of the Small Business Administration (SBA). It is a voluminous data base constructed from the credit records of Dun and Bradstreet and other private sources. It includes data on employment and other financial information. More importantly, it also specifically identifies branch plants and their parent firms. Thus, it is a longitudinal file of individual establishments with which the researcher can study establishment births, deaths, expansions, and contractions, among other topics. There are questions about the completeness and accuracy of this source, but the SBA has attempted to verify and check the data. There is no occupational or technology content in the data base, but it remains a possibility for use in future research studies.

As stated earlier, there are many data bases that have a regional dimension. Some of these have been discussed in other sections, such as the CPS or the OES programs, so it serves little purpose to repeat those discussions here. In general, the more specific the geographic focus, the less adequate the data available. Data are withheld to prevent disclosure, and noncomparabilities and inconsistencies abound in area and industry data. These problems tend to be much more acute than at the national level, and thus the data series tend to be far less comprehensive.

Selected Examples of Research

In this section selected examples of research that have explored the impacts of technological change are discussed, highlighting the role that the data sources played in the analysis. This critical review is limited in a number of ways. First, time and cost constraints did not permit us to explore the full scholarly literature. Second, the review is not strictly limited to the employment impacts of technological change because some of the research reviewed has addressed other concerns as well. Third, there is an unmistakable bias toward economic research. The purpose of the review is to provide some insight about the data sources utilized in a variety of research approaches rather than to comprehensively review the literature on the employment effects of technological change.

There is a voluminous economic literature about technological change, economic growth, productivity growth, research and development activity, etc., but the articles that address the employment impacts of technological change are much less numerous. The recent research studies of Denny and Fuss, Leontief and Duchin, the Office of Technology Assessment (OTA) of the U.S. Congress, Smith and Wilson, Ayres and Miller, Rumberger, Mansfield, and Scherer are reviewed. Four of the studies address the employment implications of technological change directly--Denny-Fuss, Leontief-Duchin, OTA, and Ayres-Miller, while another (Rumberger) addresses it indirectly. The three remaining efforts address other aspects of technological change. They illustrate the difficulties of measuring technology and demonstrate the state-of-the-art in analyzing technological change.

Denny-Fuss

Michael Denny and Melvyn Fuss (1983) estimated the impact of automation on the occupational demand for labor by Bell Canada. The researchers had access to a unique micro data set at the level of the firm. Detailed data were available on four occupational groups: operators, plant craftsmen, clerical workers, and the diverse category of white-collar workers. Technological change in the firm was measured by a single indicator--the percentage of telephones with access to direct distance dialing. Data were also available on material costs, and the capital stock was constructed using the perpetual inventory method.

Denny and Fuss use standard economic production function theory but they estimate the model in a two-stage process employing the newer flexible functional forms now common in the economic literature. Among other advantages, these newer functional forms, such as translog, do not restrict the substitution possibilities between inputs. Thus, they permit testing of some of the assumptions of production theory itself. Furthermore, they facilitate the consideration of technical change within the production function approach.

Denny and Fuss conclude that for Bell Canada the technical change examined was significantly labor-saving for all four occupational groups, but especially for operators, who were directly affected by the technology. In general, technical change had the most adverse impact on the least-skilled occupations. On the other hand, as one might expect, output growth had positive impacts on all occupations, but the greatest positive impacts occurred in the most highly skilled positions.

The Denny-Fuss study appears to be unique among production function studies in its use of an explicit measure of technology in assessing the occupational demand for labor. While some might criticize the highly formalized assumptions of production theory, the Denny-Fuss methodology offers the significant promise of untangling the separate influences of output levels, factor prices, and technological change in order to isolate the role that each has played in contributing to changes in employment levels. Obviously, this is an exciting development in the study of process technology that is used directly to produce goods and services.

On the other hand, no econometric estimation techniques can handle hundreds of detailed occupations or dozens of different technology indicators. The data are not of sufficient quality to permit this type of analysis, nor are such historical data available in the case of most technological change. Still, the newer flexible econometric production functions permit testing for consistent aggregates. Thus, some advances in empirical work, such as the Denny-Fuss research, are possible if meaningful technology indicators can be constructed.

One final comment that is applicable to the Denny-Fuss research as well as to the other research reviewed here: The fitting of historical data, however elegant the procedure, does not provide total insight regarding future technological change. One might argue that it provides no insight whatsoever about new technologies. While analogies may be indicative, no one seriously believes that the diffusion of machine tools or computers helps determine the diffusion of robots. Process technologies tend to be unique and specific to the industries that utilize them. So historical studies of technological change help us understand what has taken place in the past but do not provide us with an infallible forecasting tool.

Leontief-Duchin

Wassily Leontief and Faye Duchin (1984) have attempted to isolate the impact of computer-based technologies on employment by industry and occupation. They use a comprehensive input-output (I/O) framework with four separate but interrelated matrices. The model is dynamic in that investment is a function of output changes in the individual producing sectors. The Leontief-Duchin study begins with the various BEA I/O tables, including the preliminary 1977 tables (unpublished by BEA at time of writing) and the census-based employment data by occupation. The key forecasting task is to alter the individual technical coefficients in the producing and using sectors to account for the new computer-based automation.

The analysis is limited to robots, computers, computer-numerically controlled (CNC) machine tools, electronic office equipment, electronic education devices, and the industries that will use the aforementioned equipment. The technological forecasting is open in that the assumptions are clearly stated and based primarily upon the expert judgment of the researchers. The overall model is then driven by the same final demand forecast used by the Bureau of Labor Statistics in the OES occupational projection effort.

Leontief and Duchin conclude that there will probably not be a labor surplus by the year 2000 due to the introduction of computer-based technologies. They find significant gains in employment due to the production of capital goods. Thus, however surprising it may appear to some, the projected total employment of blue-collar workers in the economy does not fall, even with significant automation, because these workers are also important in the production of capital goods.

There are no particular problems with the underlying input-output data of the Leontief-Duchin study. However, there are serious questions about some of the technological assumptions that drive the conclusions of the model. For instance, clerical workers are forecast to decrease in importance relatively and absolutely. This occurs because the study assumes that the productivity gains attributable to office automation will outweigh any work-creating aspects of the technology, and the technology itself is assumed to diffuse widely throughout the economy during the forecast period. Obviously, this scenario will lead to a decline in the number of clerical workers, but it is important to understand that this result is built into the assumptions of the model; it is not an outcome of the model. Reasonable people have always disagreed about these kinds of judgments, especially when they apply to future events.

Twenty years ago many experts were also predicting severe declines in clerical occupations due to the introduction of computers, but these occupations actually grew in importance, both relatively and absolutely. In fact, throughout the last recession white-collar jobs continued to expand even as the total number of jobs in the economy fell. These comments are not offered to indicate that the Leontief-Duchin assumptions are wrong but rather to indicate how treacherous such assumptions can be and how sensitive the conclusions may be to the assumptions.

A second major problem arises in the Leontief-Duchin study because one of the assumptions is that no technical change outside computer-based technologies is allowed to affect future employment levels. This leads to projection of dramatic gains in employment for occupations that are largely unaffected by computer technologies such as farmers, bakers, truckers, etc. While this assumption isolates the pure impact of computers in a modeling sense, the Leontief-Duchin approach seriously limits the usefulness of the occupational projections. No one seriously believes that farmers, bakers, and truckers will be the growth jobs of the future.

In short, the Leontief-Duchin study is a heroic attempt to model the employment effects of technological change. However, the model itself merely provides a way of working out the implications of the judgmental assumptions about technological change. In our opinion, the current version of the model does not permit valid generalizations about the probable employment impacts of technological change.

Office of Technology Assessment

Perhaps the best example of the kind of research that can be done without a more adequate data base is the study by the Office of Technology Assessment (OTA) of the U.S. Congress (1983), which assesses the impacts of computerized manufacturing automation. The OTA approach must be termed eclectic. OTA commissioned case studies of individual applications of technologies, utilized a panel of experts to estimate the likelihood and probable date of specific technological breakthroughs, sought empirical data wherever possible, and gained the input of individual expert advisors, among other activities.

The OTA study can actually be regarded as a synthesis of the available data and opinions of many experts about technological change and its impacts. OTA concludes that the emerging technologies are too embryonic to forecast specific quantitative changes in employment. But the study does identify the likely direction of change and the probable areas of greatest impact. The validity of the qualitative conclusions, as in other studies, rests with the adequacy of the judgments of the authors of the study and the experts they consulted. It is instructive to examine briefly how OTA uses available data in arriving at its qualitative conclusions.

One of the major themes of the OTA study is the possibility that the emerging automation technologies may exacerbate the employment problems that already exist in the Great Lakes and Middle Atlantic states. OTA notes that these regions are heavily concentrated in manufacturing employment both relatively and absolutely (economic census of manufactures data). Furthermore, a disproportionate share of that employment tends to be found in the traditional metalworking industries of autos, appliances, steel, machine tools, etc., which may be most susceptible to the emerging automation technologies (expert opinion). OTA also shows that, historically, states with heavy concentrations of manufacturing have tended to have well above average rates of unemployment, and that the current rates of unemployment are high in these areas (CPS data). Finally, OTA notes that many forecasters think that the growth in demand for the products of the metalworking sector, especially autos and steel, may be laggard in the future. Obviously, this is not a direct "cause and effect" chain of reasoning but represents the considered judgment of the authors based on some quantitative descriptive data and the expert opinion of others.

Another major portion of the OTA study examines the future of specific occupations, again in qualitative terms. OTA utilizes the OES data of BLS frequently in this section. It also cites the NSF data on scientific and technical personnel in assessing the future demand for engineers. It utilizes the economic census of manufactures data to show that the growth in technicians between 1977 and 1980 exceeded the growth of engineers, thus suggesting that technicians are being substituted for engineers. OTA also describes the technologies and the effects that these technologies may have on specific occupations, a description largely based on expert opinion.

The utilization of data in the OTA study is exhaustive. The authors seem to have tapped all the major data sources. Furthermore, it is exemplary that OTA did not make comparisons of data across sources or over time that were basically noncomparable. However, the authors did not provide a unified theoretical or analytical structure within which their methods and results could be easily summarized. It is therefore difficult to objectively assess some of the qualitative conclusions, because one cannot be certain on what data or opinions those conclusions are actually based. Many of the case studies are also not published, probably because the firms requested anonymity. In brief, this eclectic, qualitative approach, while it may represent the best judgment available about the impacts of technological change, cannot be easily evaluated or related to other data bases and studies.

Smith-Wilson

The University of Michigan/Society of Manufacturing Engineers (UM/SME) Delphi forecast of industrial robots, authored by Donald N. Smith and Richard C. Wilson (1982), assesses future trends in robotics. The current UM/SME Delphi forecast reports results of three rounds of questioning on many technical, marketing, and sociological aspects of the development of industrial robots. Over 200 questions were asked in round one, while rounds two and three repeated some questions of round one as well as adding supplemental questions suggested by the experts. The total number of participants ranged from 36 to 60, with as many as 90 percent from corporate user firms.

The Delphi technique itself is one method of gathering expert opinion about subjects where there may be little or no known facts. It is an iterative forecasting process in which experts independently input their own forecasts of the future by responding to a consistent series of questions. The objective of the Delphi methodology is to gain consensus through iterative polling. The assumption is that the collective opinion of the group is better than that of any single person. It should be mentioned that the current UM/SME Delphi forecast is an interim report and does not yet meet the usual Delphi requirements for consensus and precision.

The specific UM/SME Delphi forecasts are not of interest to this study. From the standpoint of data analysis, however, the significant feature of this study and other similar polling techniques is that they represent attempts to construct data in the absence of facts. The UM/SME Delphi study estimates the current population of robots as well as the future population of robots and current displacement per robot as well as future displacement per robot, among many other variables. The adequacy and quality of the estimates depend on factors such as the quality of the experts who participate in the polling, the clarity of the questions, etc.

One of the difficulties of this approach is that the questions must be framed in such a way that they truly probe the expertise of those polled rather than encourage wild speculations. Nonetheless, this approach may be useful in situations where it is too early for systematic data collection, case studies, or other methods of inquiry. It offers the advantage of systematizing the judgments of many people rather than depending on the judgments of only a few people, albeit with no way of being sure that the collective judgment is truly well informed.

Ayres-Miller

Robert Ayres and Steven Miller (1983) of Carnegie-Mellon University have also addressed the displacement potential of robotics. The basis of the job displacement estimates of Ayres and Miller is a survey of corporate users of robots (with 16 respondents) that asked them to provide estimates of potential job displacement in 32 occupations by today's commercially available robots and tomorrow's robots that would be sensor-based with rudimentally tactile and/or visual perception. The occupations were chosen by Ayres and Miller as those most likely to be robotized. The responses were weighted by size of firm (six classes) to obtain a weighted-average response. These sampled occupations were then combined with other nonsampled occupations (based on similarity), and job displacement estimates were derived for manufacturing.

The occupational data utilized in the Ayres-Miller study were the OES data from BLS. These employment-by-occupation estimates were multiplied by the survey results for the potential displacement in those occupations due to robots to arrive at total potential displacement for manufacturing. According to Ayres and Miller (1983:205), today's commercially available robots could theoretically replace 1.5 million manufacturing workers while tomorrow's more sophisticated robots could theoretically replace an additional 4 million workers.

The Ayres-Miller research illustrates the dangers of overgeneralization from a narrow empirical base. Using their very small sample of survey responses, they generalize to a broad group of occupations and industries that they believe may be affected by robotics technology. Even granting that the authors are attempting to estimate the engineering potential for robots in the unbounded future, all welders in a particular industry are not necessarily performing the same work tasks, nor are industries similar in terms of production techniques. In other words, neither occupations nor industries are homogeneous in terms of the work tasks that may be automated by new technology. Thus, in our opinion the Ayres-Miller projections rest on a false generalization about the nature of manufacturing.

There is also some question about the validity of the survey on which the estimates of potential displacement are based. Sixteen respondents are an extremely meager sample from which to estimate the potential displacement due to robots for all of manufacturing. Furthermore, the largest number of firms using robots in 1981 (the date of the survey) were auto or auto-related, and the weighting procedure appears to favor large firms. Thus, the survey results may be more representative of large auto firms than of all manufacturing.

In short, in our view Ayres-Miller overgeneralized in forecasting the employment effects of technological change. Their empirical base was not sufficient to make broad displacement forecasts. Technological change tends to be very specific to industries and specific work tasks within industries. Simple extrapolations from readily available data may not be an adequate guide to policy.

Rumberger

Russell Rumberger (1981) estimates the change in skill distribution due to (1) shifts in occupational employment and (2) shifts in skill requirements within individual occupations. The data for individual occupational skill requirements are from the third and fourth editions of the Dictionary of Occupational Titles (DOT), published in 1965 and 1977, respectively. The second set of data, that for the distribution of employment, comes from the 1 in 1,000 Public Use Sample, published in 1960, and the 1976 Current Population Survey (CPS).

Since the census occupations employ a different coding scheme from the DOT, and all four of the coding schemes changed between 1960 and 1976, Rumberger faced a major task in splicing these series together and in making intertemporal comparisons. First, Rumberger found other research that cross-referenced the CPS to census occupation codes as well as to DOT codes. Using this information, Rumberger was able to specify or assign the probability that a specific General Education

Development (GED) level from the DOT was likely to be associated with a specific census occupation. The GED skill level thus becomes the measurement of the average skill requirement for individual occupations. Finally, another cross-reference had to be used to translate the third edition DOT information into equivalent fourth edition information. For instance, the fourth edition DOT reports three components for the GED scales while the third edition reports only one. Finally, all of these data are aggregated to the major occupational group level (11 occupational groups) for the comparisons in the study.

Rumberger concludes that changes in the distribution of occupational employment increased average skill levels, while changes within individual occupations narrowed skill level differentials. In particular, within occupations there was a decrease in the percentage of jobs that required the highest levels and those that required the lowest levels of skills. Rumberger admits that these results should be viewed with caution and says the major difficulty in all of these studies is combining DOT data with census data.

Because of the widespread tendency of other researchers to misuse the DOT, it is worth reviewing this document in more detail. While the DOT may appear to be the richest vein of occupational information in the United States, it is only a description of occupational content, completed over a long period of time by the employment service to provide detailed information about occupations based on the tasks performed in those occupations. It was designed to be used to match applicants with jobs. Data are collected on 46 variables in all.

The General Education Development levels, of which there are six, represent the judgments of the interviewers rather than any hard set of tangible criteria. The interviews for the third edition of the DOT occurred throughout the early 1960s while the interviews for the fourth edition of the DOT were completed between 1965 and the mid-1970s. According to a National Academy of Sciences study (Miller et al., 1980), over two-thirds of the occupations described in the fourth edition of the DOT reflect three or fewer interviews. According to them (Miller et al., 1980:10), "the extent to which the occupational descriptions rest on such limited observations raises some question about their adequacy."

The actual sampling for interviews was somewhat haphazard. First, the national office of the employment service assigned particular industries to 11 field offices. The field offices then chose "typical" establishments within those industries. Finally, the field offices negotiated with the employers to secure their agreement on the type and number of jobs to be evaluated. Approximately 75,000 job descriptions were completed in this way, ranging from 762 for material handlers to none for 16 percent of the more than 12,000 occupations in the DOT. Obviously, the DOT is not based upon a random sample, nor do the GED levels reflect skill levels in an objective way.

Perhaps Russell Rumberger should be applauded for making this effort to estimate the changing skill requirements of jobs in the United States. However, the data sources utilized really do not permit the kind of analysis undertaken. The basic problem is that Rumberger linked four essentially noncomparable data sets to answer questions that none of the data sets were intended to answer. The result is that it is impossible to tell which employment effects are real and which are induced by the specific measurements used and the crosswalks between data bases.

Mansfield

Edwin Mansfield of the University of Pennsylvania has devoted much of his professional life to the study of technological change. One of his early contributions was the development and fitting of logistics curves, the parameters of which measure the rate of diffusion of a specific technology. Mansfield has also been interested in organizational factors that affect success in R&D and social and private rates of return from industrial innovations, and has conducted numerous studies of specific innovations in firms and/or industries. For an introduction to the Mansfield work the interested reader might consult his most recent book, The Production and Application of New Industrial Technology (1977).

In a recent paper Mansfield (1983) attempts to determine the effect of technological change on industrial concentration. The primary data were obtained from a random survey of 34 firms that voluntarily participated in the study. These 9 chemical, 12 petroleum, and 4 steel firms all agreed to indicate the scale effect of major process innovations since 1920. The process innovations themselves were drawn at random from published lists of major new processes. In this first part of the research Mansfield concluded that process innovations were overwhelmingly scale-increasing. In other words, they increased the cost advantage of large firms. He also concluded that there has been no change in this result since 1950. Indeed, he found that the proportion of scale-increasing innovations was actually higher in the more recent period.

In the second part of the research Mansfield asked these firms to assess the effect of major product innovations on the four-firm concentration ratio (a common measure of market power) in that industry. In the petroleum and steel industries product innovations were overwhelmingly concentration-increasing, while in the chemical industry there was no discernible trend. To test whether the perceptions of those surveyed reflected actual developments in those industries, Mansfield regressed the observed changes in the concentration ratios in these industries on the percent of product innovations that were perceived to be concentration-increasing from the survey. The correlation was moderate ($r=.51$) but statistically significant only at the 0.10 level.

This recent research is particularly interesting because it illustrates a number of points about data sources that recur frequently in other studies of technological change. First, data on technological change are generally not available directly. If the research requires such data, that dictates the need for an original survey. Second, the results of these surveys, based upon the perceptions and knowledge of the interviewees only, are not necessarily conclusive. At best they illustrate what happened historically in a particular industry. Nevertheless, there have been and likely will continue to be many one-time specialized data sources developed to study some aspect of technological change. Each of these data sets is unique and noncomparable, but they can provide valuable insights into the implications of technological change.

Scherer

In recent years F. M. Scherer has attempted to mine one particular data set extensively--the Federal Trade Commission's Annual Line of Business Survey, now discontinued. This data base covers 443 corporations that account for about three-fourths of private firm R&D outlays. Scherer linked these data with patent data (classified as process or product technology), industries of origin and utilization, and in other ways. One of Scherer's major contributions was the construction of an interindustry matrix of technology flows. This matrix depicts an industry's own R&D performance as well as its use of R&D from other industries. This is important because some sectors, such as services, rely almost exclusively on R&D performed outside the sector. Thus, substantial technological change may occur without a sector performing the research that causes that change.

In a recent article Scherer (1983) investigates the possible role of R&D in contributing to the well-publicized productivity decline of the 1970s. The technology flows matrix is used to derive R&D estimates for 25 industries at roughly the two-digit SIC code level. Then that information is utilized in a relatively simple productivity regression following Terleckyj (1974). Specifically, the change in labor productivity is estimated as a function of the change in the capital-labor ratio, the rate of return on R&D expenditures, and, of course, the technology flows relative to output. Actually, the technology data are measured in three different ways--product R&D, process R&D, and R&D imported from other industries. Scherer concludes that the 1970s productivity slump did not result from a fall in the productivity of R&D.

The Scherer research illustrates once again the necessity of developing an original data set--one that may have taken several person-years to construct--to explore the impacts of technological change. It is also interesting to note that the particular starting point for this effort, the Federal Trade Commission's Line of Business Survey, has now been discontinued due to budget considerations. Scherer (1983:218) calls this survey the "best disaggregated data on R&D spending." While that may be true, it is still limited to R&D outlays (both company-financed and under contract, mostly to the federal government). Thus, the key to constructing the technology flows matrix is to link the patents data, appropriately lagged, to the R&D spending, to identify the patent as process or product oriented, and to determine whether the patent was used internally or sold as a product externally. Obviously, these tasks require considerable painstaking effort and judgment.

In both the Mansfield and Scherer research the technology measures are indirect, relatively unidimensional, and highly aggregated. Mansfield's survey of major process innovations assesses the direction of the scale effects, while Scherer attempts to disentangle process from product R&D spending. Neither author asserts that these measures are anything more than crude approximations or surrogates for technology and technological change. Mansfield (1983:205) notes that, "we know little or nothing about the effects of the various process and product innovations that have occurred in recent years in various industries." We have barely begun to systematically construct measures of the technology that is used to produce goods and services.

Summary

The Mansfield and Scherer studies clearly illustrate the data problems in studying technological change. Most of the economic research on technological change uses indirect estimates of capital input. This is not a matter of choice, but of necessity, since such data have not been developed. The best empirical work is that characterized by intensive data mining or special field work that yields more specific measures of capital inputs to the productive process. One of the reasons that the Denny-Fuss research shows promise is that the authors were able to construct a technological indicator; another is their use of the newer flexible functional forms.

Several studies that may have seriously misused the data have also been reviewed. Ayres-Miller applied limited survey results about displacement due to robots across occupations and industries that may in reality be quite heterogeneous. Rumberger attempted to determine the direction of skill levels in the United States using data sets that are so inconsistent that it is difficult to interpret or judge the results. One cannot tell whether the results are representative of the facts or merely reflect the "noise" introduced by the measurement and translation process. This is not to impugn the motives of these researchers in any way; when the question is important enough that it must be answered, one makes do with whatever is available. But this also does not mean that the answer is satisfactory or cannot be improved upon with better data or more sophisticated analysis.

Finally, a theme that emerges clearly from the discussion of the selected examples of research is that a heavy dose of judgment may be required to bridge the gaps in data for the study of technology and employment. The Delphi technique is one method to gather expert opinions or judgments and to create data in the absence of any facts at all. Leontief and Duchin developed a new I/O model that will prove to be extremely valuable in working out the implications of particular technological assumptions. But these assumptions still are based on judgment. Finally, the OTA study found the data so insufficient that they were forced to rely on description and qualitative reasoning in their analysis as well. It is significant that the OTA study, which is the most thorough and comprehensive in terms of assessing the technologies and their impact on employment and the workplace, ultimately used judgment to determine the probable trends in employment and technology.

The conclusion to be drawn from these studies is that there is a wide variety of approaches to the study of the employment implications of technolgical change. They all suffer from the lack of an adequate data base. What has been demonstrated here is the ingenuity of the research community in trying to overcome this basic deficiency in the data.

CONCLUSIONS AND RECOMMENDATIONS

The shortcomings in the data available to study the employment effects of technological change have been emphasized repeatedly throughout this paper. The gap between existing data sources and the ideal data base for the study of technological change and employment has been explored. While many of the desired elements are present in one data source or another, there is nothing close to an integrated data source that can address the critical variables for such a study.

To some degree the essence of change in process technology is the substitution of machines, or capital, for labor. It is also true that the nature of productive processes tends to be specific to given products. Thus, to study the employment impacts of process technology changes, we must be able to measure both capital and labor as inputs to the firms in a given industry. Since these measures are generally not available, it is difficult to study the past or present employment effects of technological change, let alone forecast future impacts.

Office automation and the use of computers in business are not new. The first computer revolution occurred 25 years ago when electronic data processing began to enter our offices and factories. How much do we know about the past diffusion of computers? What were the employment effects? How did computers affect the skills required for employment? Clearly, the problems of forecasting the future employment effects of technological change discussed in the introduction of this paper are compounded by our lack of knowledge of such impacts in the past. This in turn reflects the lack of adequate data with which to study the employment effects of technological change.

We have occupational data, but it cannot be linked to specific technologies in use. We have demographic data, but it does not possess sufficient occupational or technological content. In the area of the technology itself, we lack even the most rudimentary data with which to address policy concerns.

The existing federal statistical system has not been able to solve these problems. This system is a natural outgrowth of the administrative requirements of the individual agencies or the data needs of the constituent population served by those agencies. The system produces reasonably high-quality data; it is also reliable if used for the purposes originally intended. But this system has led to a patchwork quilt of data sources. Currently, there does not appear to be a strong movement to support the integration of some of the data bases. In addition, potential progress on this front has been forestalled by the wave of budget cutting that has been sweeping over data collection efforts recently.

If we are to design policies to prepare for technological change, we must have better information than we have right now. The intense interest over the last few years on the part of policymakers in the employment implications of technological change has not drawn forth a definitive analysis of the problem. In truth it cannot, because the empirical base to support such a definitive analysis does not exist. This review has concentrated on these gaps in knowledge. Now it is time to discuss what can be done to begin to close these gaps so that we can effectively grapple with the challenge of the employment impacts of technological change.

New Initiatives in Data Collection

Highest priority should be given to the development of a new, comprehensive data base to study the employment effects of technological change. These data must be collected from the firm; there is no other feasible approach. We have stressed throughout this paper that establishment-oriented data are critical because it is only at the level of the firm that all of the data items required can be gathered in a consistent way.

We recommend the development of a "Current Establishment Survey" of firms to parallel the Current Population Survey of households. A nationally representative sample of firms stratified by industry and size would be surveyed periodically to measure technology in use, investment activity (changes in technology), employment by occupation, raw material inputs, shipments of finished goods, inventory levels, sales, and other variables of interest. In this way inputs and outputs of the productive process could be measured consistently at the appropriate level of observation. Occupational employment data collected within such a comprehensive framework would be infinitely more valuable in explaining occupational employment trends.

We are cognizant of the difficulties in implementing such a new survey. Technical issues such as a reliable method for enumerating technologies would require some development. Sampling strategies and optimum periodicity of observation would have to be worked out. Costs would need to be carefully estimated. It is to be understood that such an initiative would have to be coordinated with existing data programs. A survey of this type would be extremely useful in updating data from the Census of Manufactures and other major data sources. It should also be useful in extending them, to nonmanufacturing sectors, for instance. Such a survey could be valuable in updating input-output tables that are so expensive to produce but that can become outdated in a few years. With careful design, we believe such a data collection effort would repay the required investment many times over.

Regardless of whether a new, comprehensive establishment-based data source is to be instituted, it is vital to consider the development of technological indicators that make it possible to track the diffusion of specific technologies. Such indicators might include the number of robots in use by application and industry, the number of computers being applied in different environments, or the type and number of word processors installed. In the not too distant future we might wish to know the number and type of artificial intelligence or voice recognition systems in place, among other emerging technologies.

To illustrate an incremental and cost-effective way to develop technological indicators for a specific technology, consider the case of robotics. At the simplest level a question might be appended to the Annual Survey of Manufactures asking whether the establishment is a robot-user, and if so, how many robots? That would provide for the first time tabulations of the number of user establishments cross-referenced to the other data collected in this survey such as the size of the establishment, SIC code, etc. The number of robot-users by size of establishment might be particularly interesting because the common wisdom today is that these users are large firms. With annual data it would be possible to track the diffusion of robotics to progressively smaller establishments. Although this approach would provide no information about the occupations affected by robotics, it would be possible to follow overall employment trends in establishments using robots.

Direct measures of technology should make it possible to take the indicative or qualitative research efforts such as the OTA study a little farther down the line. The research of Denny and Fuss is one example of what can be accomplished if technological indicators are available. Without measurement of the technologies, however, there is no way to determine specific occupational impacts. Thus, the key to unlocking the black box of technology and employment is to link for the first time selected technological indicators to occupational employment in a systematic way at the level of the firm.

Although more comprehensive data collection is a necessity if we are to gain an adequate understanding of the occupational impacts of technological change, the cost of data collection for the reporting units must be weighed as well. A thorough review of current data collection efforts should be conducted with the intention of improving the overall efficiency of data collection. We believe that elimination of some data requests or aggressive consolidation efforts could result in a net decrease in the burden of reporting, even with the new initiative outlined above. A key principle is that business firms must see the value of information collection. A major share of the resistance to data reporting currently comes from a conviction that nothing useful is ever done with the information tendered. We believe it is essential that the business community be convinced of the usefulness of such information for vital policy purposes. Without their commitment, such a program is not feasible.

Making Better Use of Existing Data

Greater priority should also be given to the full use and integration of existing data bases. This approach would improve data effectiveness and not add to the paperwork burden imposed by the federal government on private firms. As stated earlier, the existing data are not necessarily bad; they are just not linked to each other in any meaningful way. The Small Business Administration data base, the development of which is actually ongoing, represents one such attempt to build a relatively thorough data base on the firm or establishment level by combining many independent series. The more complete the better; much more of this work needs to be done, particularly if an integrated data base cannot be developed.

Most of the economic research on technological change uses indirect estimates of capital input. This is not a matter of choice but of necessity since adequate direct measures have not been developed. The best empirical work is that characterized by intensive data mining or special fieldwork that yields more specific measures of capital inputs to the productive process. Frequently, this occurs in case studies of firms or industries, because only by restricting the variety of productive processes can sufficient specificity be achieved to yield useful results. But then the generality of the results is compromised.

It may be that there is no way around this problem. Since the nature of productive processes tends to be specific to given products, there will always be a trade-off between specificity and generality. Accepting the fact that technologies tend to be specific in application, firm or industry case studies may be the most appropriate way to study the employment effects of technological change.

Nevertheless, it is critical to try and find a way to systematize the results from narrow case studies. Both the BLS occupational projections program and the Leontief-Duchin model offer some hope in this regard. The occupational-industrial employment matrix appears promising as a device to help systematize the impacts of technology on specific occupations in specific industries. If such an organizational framework guided the design and interpretation of individual case studies, the generality of such efforts could be improved. At a minimum it would be possible to focus the intelligence gained from each separate case study.

If we are serious about studying the employment impacts of technological change, the OES occupational projection system of the Bureau of Labor Statistics requires further nurturance and development. Actually, there have been only two complete national OES surveys to date, so the OES system remains a relatively new data base. It is the major federal program designed to provide occupational data. It may also be the leading candidate to develop the scope and generality to accommodate the immense quantity of specific data necessary to accomplish the goal of building a data base adequate to cope with the issues of employment and technological change.

There are other data bases that offer promise in studying the employment effects of technological change. The NSF surveys of scientific and technical personnel appear promising for the study of those occupations, including the age, gender, and race characteristics. The EEO-1 data are definitely underutilized. Although limited in terms of the occupational content, the EEO-1 data are strong in demographic and industrial content. What is needed to greatly improve the EEO-1 data is a random sample of smaller firms by industry so that sample estimates of the universe of all firms are possible.

There is also a need to establish priorities across the agencies that produce data and the users of those data. The Office of Management and Budget plans to revise the SIC system by 1987. How can we update and change definitions yet retain consistency in the data? Can we reduce some of the minor differences in data across agencies that render those sources noncomparable? Could data collection efforts of different agencies be combined to reduce the burden on respondents? How can we make more data available to researchers without loss of confidentiality? If there is a social need for integration of the data to study the employment effects of technological change, then we must develop a plan of action to satisfy those needs.

It would be a significant contribution if data could be made available on a more timely basis and in machine-retrievable form. Five-year lags between gathering and publishing data are not acceptable. Perhaps some federal agencies need some "induced" technological change to help accelerate this process. Machine retrieval is also important to speed up distribution and improve accuracy of analysis. The microcomputer revolution is upon us, but the statistical gathering efforts are not adapting rapidly enough in some cases.

As a society we need to come to grips with the ultimate forecasting questions. How much can we know about the future? How much is necessary for us to know in order to prepare for the future? We should concentrate our efforts on improving our information where it is most critical and most productive. In our opinion, technological change becomes virtually impossible to anticipate much beyond a 10-year planning horizon. Occupational forecasts based on technological change will accordingly lose some realism beyond that point. Why squander precious resources on trying to forecast the unknowable?

In the long run technological progress has significantly raised our living standards and improved the quality of our lives. In the short run, however, it has caused disruption of the lives of some individuals and occasionally led to social conflict. Will this pattern be repeated in the case of the microprocessor revolution? The truth is that no one knows, but it is possible to gain far better insights into the impacts of technology on employment by improving the data available to study the subject.

REFERENCES

Alexander, Lois A., and Jabine, Thomas B.
1978 Access to social security microdata files for research and statistical purposes. Social Security Bulletin (August):3-17.

Ayres, Robert, and Miller, Steven
1983 Robotics: Applications and Social Implications. Cambridge, Mass.: Ballinger Publishing Company.

Bureau of the Census
1982 1980 Census of Population: Classified Index of Industries and Occupations. Washington, D.C.: U.S. Department of Commerce.

Denny, Michael, and Fuss, Melvyn
1983 The effects of factor prices and technological change on the occupational demand for labor: evidence from Canadian telecommunications. Journal of Human Resources (Spring):161-176.

Employment and Training Administration
1977 Dictionary of Occupational Titles. Washington, D.C.: U.S. Department of Labor. Fourth edition.

Gold, Bela
1981 Robotics, programmable automation and increasing competitiveness. Pp. 91-117 in Office of Technology Assessment, Exploratory Workshop on the Social Impacts of Robotics: Summary and Issues. Available from the U.S. Government Printing Office. Washington, D.C.: Office of Technology Assessment, U.S. Congress.

Kendrick, John W., and Lee, Kyu S.
1976 Quarterly estimates of capital stocks in the U.S. private domestic economy, by major industry groups. Review of Income and Wealth (December):345-352.

Klein, Deborah P.
1984 Occupational employment statistics for 1972-82. Employment and Earnings (January):13.

Leontief, Wassily, and Duchin, Faye
1984 The Impacts of Automation on Employment, 1963-2000. Final report to National Science Foundation. New York: Institute for Economic Analysis, New York University.

Mansfield, Edwin
1983 Technological change and market structure: an empirical study. American Economic Review (May):205-209.

Mansfield, Edwin, Rapoport, John, Romeo, Anthony, Villani, Edmund, Wagner, Samuel, and Husic, Frank
1977 The Production and Application of New Industrial Technology. New York: W. W. Norton.

Miller, Ann, Treiman, Donald J., Cain, Pamela S., and Roos, Patricia A., eds.
1980 Work, Jobs and Occupations: A Critical Review of the *Dictionary of Occupational Titles*. Washington, D.C.: National Academy Press.

Office of Economic Growth and Employment Projections
1981 Projected Occupational Staffing Patterns of Industries. OES Technical Paper No. 2. Washington, D.C.: U.S. Department of Labor.

Office of Technology Assessment
1983 Computerized Manufacturing Automation: Employment, Education, and the Workplace. Available from the U.S. Government Printing Office. Washington, D.C.: Office of Technology Assessment, U.S. Congress.

Rumberger, Russell W.
1981 The changing skill requirements of jobs in the U.S. economy. Industrial and Labor Relations Review (July):578-590.

Scherer, F.M.
1983 R&D and declining productivity growth. American Economic Review (May):215-218.

Smith, Donald N., and Wilson, Richard C.
1982 Industrial Robots: A Delphi Forecast of Markets and Technology. Dearborn, Mich.: Society of Manufacturing Engineers.

Stanford Research Institute
1984 Drop in business demand for personal computers. The SRI Journal (May):4-5.

Stinson, John F., Jr.
1984 Comparison of nonagricultural employment estimates from two surveys. Employment and Earnings (March):6-9.

Terleckyj, Nestor
1974 Effects of R&D on the Productivity Growth of Industries. Washington, D.C.: National Planning Association.

Vaughan, Roger J.
1977 The Urban Impacts of Federal Policies. Vol. 2: Economic Development. Santa Monica, Calif.: The Rand Corporation.

Whitley, J. D., and Wilson, R. A.
1982 Quantifying the employment effects of micro-electronics. Futures (December):486-495.

APPENDIX: DATA SOURCES

Guide to Data Sources

In the second major section of this paper the available data sources were assessed on the basis of the following dimensions: technology, occupations, demographics, and areas and industries. The primary purpose of this appendix is to present the major available data bases themselves. There is first, however, a very brief discussion of the criteria that were used to select these data bases.

The available data bases fall far short of the ideal data base described in the introductory section of this paper. In many cases the occupational, technological, and demographic characteristics appear to form mutually exclusive sets. In those cases in which two or more of the characteristics are present in a single data base, such as the CPS, the data are not always comparable over time. For these reasons, the tables that follow include all major data bases that qualified on the basis of any one of the critical characteristics of technology, occupations, or demographics.

The second criterion chosen was that the data base must be an ongoing, continuous time-series of observations in which the series are reasonably accessible to researchers. This criterion excluded the innumerable specialized data sets that have been assembled for a single study or for very narrow purposes. That is not to deny the importance of such data sets. Indeed, the authors have created one such data set themselves in accomplishing research on the employment effects of robotics.[1] But these data sets usually lack generality, become outdated very quickly, and are not of sufficient interest to a broad audience.

The tables that follow are designed to introduce researchers to the major data bases that are available to study the employment effects of technological change. As stated previously, these are ongoing data collection efforts that provide some information about one or more of the following dimensions: technology, occupations, or demographics. The tables are subdivided into two sections, government and nongovernment, and are arranged alphabetically. The government sources are differentiated from other sources primarily because their scope and coverage are so much broader. The private data tend to be fragmentary and serve special functions, except in a few instances.

The data sources are classified by the major program, survey, or census that produces the data rather than by publication or agency, although in some cases all three identifiers are the same. It should be stressed that these data bases are not the only ones available, but it is hoped that they are the major data sources subject to the aforementioned criteria. The tables include the agency responsible for

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[1] H. Allan Hunt and Timothy Hunt. Human Resource Implications of Robotics. Kalamazoo, Mich.: The W. E. Upjohn Institute for Employment Research, 1983.

the data, the publications in which the data appear, the type and frequency of data, and its demographic content, if any. The major data elements or series themselves are listed to provide the reader with some insight into the detail available in each data source, including areas and industries. The individual data items listed in the tables are not comprehensive but represent those items that might be useful in studying the employment effects of technological change. Finally, there are some short comments about each data source that attempt to clarify, evaluate, or further explain some features of the data base.

The industry identification codes in the tables are those from the Standard Industrial Classification (SIC) system. They are used by federal and state agencies to assign specific identifier codes to industries, frequently referred to as SIC codes. The broadest, 1-digit, codes encompass 11 major industries or groupings in the United States: agriculture, forestry, and fishing; mining; construction; manufacturing; transportation; communications, electric, gas, and sanitary services; wholesale trade; retail trade; finance, insurance, and real estate; services; public administration; and nonclassifiable establishments. At the 2-digit level of disaggregation there are 84 major groups, several hundred at the 3-digit level, and several thousand at the 4-digit level. The codes are assigned on the basis of the primary activity of the establishment, where an establishment is generally a single location or plant. Thus, establishments with secondary products, of which there are many in the U.S., are not distinguished separately in the SIC system.

There were undeniably many compromises necessary to summarize each data base in one or two pages. Any special references that further explain or document each data base are included in the comments section of each table. Frequently, this type of information is also available in the publications for each data source. Special mention should be made of the BLS Handbook of Methods, which provides overviews of all of the BLS statistical programs. The Bureau of the Census Catalog 1984 accomplishes the same task for that agency. Government agencies will usually consider special requests for data tabulations on a cost basis, but raw data generally is not available except in a few cases like the public-use samples from the census of population and the continuous work-history sample from the Social Security Administration.

Information about the availability of tapes in machine-readable form is included in the comment section of each table, but details on price have been omitted. The prices vary depending on the cost to produce the tape, the format of the tape, and the number of years of data desired. It is not unusual for a single reel to cost about one hundred dollars, and the more comprehensive data sources may require four to five reels for one year's data. Further information about tapes can usually be obtained directly from the agencies, the publications in which the data appear, and the publications listed in the previous paragraph. There is also a Directory of Computerized Data Files, 1984 available from the National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia.

Government Data Sources

Data Source:	Area Wage Surveys
Agency:	Bureau of Labor Statistics (BLS) U.S. Department of Labor Washington, D.C.
Publication(s):	Area Wage Surveys, Monthly Labor Review (summaries)
Type of Data:	Establishment survey of about 70 selected metropolitan areas based on a suitable sampling "frame"
Demographic Content:	Occupational employment, standard hours, and standard payroll by gender
Frequency:	Annual but individual metropolitan areas sampled throughout the year; common "reference" month established based on the combined wage data

Major Data Items	Detail	Area	Industry (SIC)
1. Employment, standard hours, and standard payroll	Selected office clerical, professional, technical, maintenance, toolroom, power plant, material movement, and custodial occupations	Nation, four broad regions, and selected SMSAs	Up to 1-digit
2. Supplementary wage benefits	Health, insurance, and pension plans, holidays, vacations, and shift differentials for plant and office workers	Nation	Up to 1-digit

Comments

The area wage surveys of BLS are designed, as the name implies, to estimate the wages of occupations common to a broad number of industries and metropolitan areas. Thus, the emphasis is clearly on wage levels. When estimates of the universe of given occupations are reported, the error can be as high as 20 percent according to the BLS (compared to 5 percent for the wage levels). Hence, the employment estimates can only be considered as rough measures.

There is considerable occupational detail in the survey, including specific job descriptions and skill-level requirements. However, the survey encompasses only selected occupations, and it is limited by the broad industrial classification scheme. The area surveys for the SMSAs are published separately from the national and regional summary.

The area wage surveys are released irregularly throughout the year as they are completed. Generally the data are not available on tape. The technical documentation for the area wage surveys can be found in the individual publications.

Data Source: BEA Capital Stock Data Base

Agency: Bureau of Economic Analysis (BEA)
U.S. Department of Commerce
Washington, D.C.

Publication(s): Fixed Reproducible Tangible Wealth in the United States, Survey of Current Business (summaries)

Type of Data: Statistical estimates based on investment data

Demographic Content: None

Frequency: Annual estimates

Major Data Items	Detail	Area	Industry (SIC)
1. Gross and net capital stocks, age of capital stock, and gross investment	Structures and equipment	None	Up to 1-digit

Comments

The BEA capital stock data base is produced for and totally consistent with the national income and product accounts (NIPA) of the United States. The data are estimates based on investment data and the "perpetual inventory method." The weak aspect of the estimating procedure is the determination of useful service lives for the components of the capital stock. Obviously, these are unobserved (and perhaps unobservable) and somewhat arbitrary. BEA's judgment is that 85 percent of the Bulletin F service lives published by the Internal Revenue Service constitutes the best service life approximation.

No information is available from this data base about the specific types of capital goods that make up the capital stock outside the broad estimates for structures and equipment. Still, these data constitute the major NIPA estimates of reproducible tangible wealth in the United States. The data are available on tape in machine-readable form on a fee basis directly from BEA.

Data Source:	BEA Input-Output Tables
Agency:	Bureau of Economic Analysis (BEA) U.S. Department of Commerce Washington, D.C.
Publication(s):	Survey of Current Business, February 1979 (summary of 1972 tables) and May 1984 (summary of 1977 tables)
Type of Data:	Statistical estimates of interindustry relationships in U.S. economy based on many census data sources
Demographic Content:	None
Frequency:	1947, 1958, 1963, 1967, 1972, 1977

Major Data Items	Detail	Area	Industry (SIC)
1. Direct and total requirements per dollar of output	None	Nation	Up to 4-digit

Comments

The direct requirements or input coefficients of an I/O table show the relative importance of the various inputs required to produce a dollar of output, e.g., 10 cents of steel for every dollar of sales of autos. The total requirements table summarizes the entire chain of events that occurs when another dollar of output is produced. For example, one more dollar of sales of autos requires not only 10 cents worth of steel directly (the direct effect), but also the production of 10 cents worth of steel itself requires additional inputs, etc. (indirect effects).

The advantages of industrial analysis utilizing I/O have long been recognized--it explicitly depicts interindustry linkages in the economy. The main disadvantage, also well known, is that each dollar of sales is presumed to have the same effects on output, both now and in the future. This constancy of input requirements denies the very existence of economic change. The recently released 1977 tables are available on tape directly from the BEA.

Data Source:	BIE Capital Stock Data Base
Agency:	Bureau of Industrial Economics (BIE) U.S. Department of Commerce Washington, D.C.
Publication(s):	U.S. Industrial Outlook
Type of Data:	Statistical estimates based on investment data
Demographic Content:	None
Frequency:	Annual estimates

Major Data Items	Detail	Area	Industry (SIC)
1. Gross and net capital stock, gross and net investment, price deflator for investment, and average age of the capital stock	Structures and equipment	None	180 manufacturing and 21 non-manufacturing industries
2. Gross and net vintage distributions of capital stock	By age-class	Same as above	Same as above

Comments

The BIE capital stock data were developed for detailed industrial analysis. BIE uses the same "perpetual inventory method" for calculating the capital stock as that used by BEA, but there are differences. For instance, BIE uses physical depreciation defined as the decline in the ability of capital to produce at a given output rather than the concepts of economic or tax depreciation. More importantly, BIE stresses the vintage of the capital stock, defined by four age-classes in their data base. This provides more information than a simple gross stock measure but obviously still lacks specificity insofar as the components of that capital stock. The data are available on tape in machine-readable form from BIE on a fee basis.

Data Source: Census of Population and Public-Use Samples

Agency: Bureau of the Census
U.S. Department of Commerce
Washington, D.C.

Publication(s): Census of Population (series)

Type of Data: Census or probability samples of individuals and households

Demographic Content: Age, gender, race, ethnicity, and education by a variety of other socioeconomic characteristics

Frequency: Decennial

Major Data Items	Detail	Area	Industry (SIC)
1. Employment and unemployment	503 occupations	Nation, states, SMSAs, and counties of 100,000+ population	Up to 3-digit
2. Income	By type (wage and salary, self-employment, social security, household, etc.)		

Comments

The census of population and the various public-use samples are one of the most voluminous data bases available to researchers. Complete census counts may include total population, age, gender, race, various household measures, and urban/rural residence. The sample data provide expanded coverage and include such items as occupation, and a variety of measures of labor force status, education, and income. All tables are clearly identified as complete counts or sample estimates.

There are two primary problems in using the census of population in studying the employment effects of technological change. First, the census is only accomplished once every 10 years, so time-series analysis is limited to very long-run trends. Second, the definitions and classification categories of individual variables in the census may change to reflect new occupations, changes in the job content of occupations, the rise and fall of industries, etc. For instance, the occupational classification system developed for the 1980 census is based on the Standard Occupational Classification Manual promulgated by the Office of Federal Statistical Policy and Standards and represents a significant departure from earlier censuses. In general, these types of changes require researchers to be extremely careful in utilizing the census of population data; the comparability of individual series over time may be tenuous.

The census of population series are generally available on a series of tapes in machine-readable form. There are also public-use microdata files (1 percent and 5 percent samples) with the individual and/or household identifiers suppressed that allow researchers to design their own tabulations. The Bureau of the Census Catalog 1984 highlights all of the available 1980 census products. The basic definition and overview of the technical documentation for individual data can generally be found in the appropriate census of population publication series.

Data Source:	Continuous Work History Sample (CWHS)
Agency:	Office of Research and Statistics Social Security Administration (SSA) Baltimore, Maryland
Publication(s):	*Earnings Distributions in the United States*, *Annual Earnings and Employment Patterns of Private Nonagricultural Employees*
Type of Data:	Based on employer reports to SSA on employee earnings and information on individuals' application forms for social security account numbers
Demographic Content:	Age, gender, race
Frequency:	Annual (1957 forward)

Major Data Items	Detail	Area	Industry (SIC)
1. Employment and payroll	Individual matched longitudinal files available from 1 percent sample	Nation, states, counties, SMSAs	Up to 4-digit

Comments

The CWHS files constitute roughly a 1 percent sample of the total Social Security Administration records. The annual employer reports on individual earnings are matched to the employee's application for a social security account number to provide demographic data (age, including year of birth, gender, and race). The CWHS data do not have occupational content, nor do they represent the complete universe of employment since the social security system covers only about 90 percent of total wage and salary employment. Still, the CWHS is a rich vein of demographic data by detailed area and industry of employment.

The CWHS is actually a system of multipurpose research files. Special tabulations are available on request for a fee subject to federal disclosure rules. Fortunately, the social security account numbers of individuals have been scrambled, so records for individuals over time can be grouped to form individual work histories (a longitudinal file). Since the base file in the CWHS is very large and very difficult to work with, various agencies and research organizations have sponsored the development of special files. For instance, the Bureau of Economic Analysis (BEA), Department of Commerce, has used the CWHS to develop the BEA Migration Analysis Data System. Researchers are advised to contact the Office of Research and Statistics, Social Security Administration, directly about the existence and availability of CWHS-based files in other organizations.

Data Source:	County Business Patterns (CBP)
Agency:	Bureau of the Census U.S. Department of Commerce Washington, D.C.
Publication(s):	County Business Patterns
Type of Data:	Virtual establishment census based upon Internal Revenue Service and Social Security Administration records and Bureau of the Census Annual Organization Survey
Demographic Content:	None
Frequency:	Annual

Major Data Items	Detail	Area	Industry (SIC)
1. Employment and payrolls	None	Nation, states, and counties	Up to 4-digit
		SMSAs	Up to 2-digit
2. Establishments	By employment-size classes	Same as above	Same as above

Comments

The CBP provides a large quantity of local and regional data by detailed industrial sector but it is limited primarily to employment and payrolls. The data exclude government employees, railroad employees, and self-employees, although federal employees are listed in separate tables. Annual reports for each state and a U.S. summary are published. Computer tapes, including some unpublished industry data, are available from the Bureau of the Census on a fee basis.

The CBP data are similar to ES-202 data, CES data, and other economic census data such as the ASM or COM, but there are various differences among these sources such as the definition of an establishment or reporting unit, timing of benchmarks for the data, and the inclusion or exclusion of self-employed. In total these differences tend to be minor, but comparisons across data sources for individual series are not advisable.

Data Source:	Current Employment Statistics (CES) (commonly called the 790 Program)
Agency:	Bureau of Labor Statistics (BLS) U.S. Department of Labor Washington, D.C.
Publication(s):	<u>Employment and Earnings</u>, including various national, state and other area supplements
Type of Data:	Nonagricultural establishment survey of about 166,000 voluntary reporting units (probability of inclusion by employment size)
Demographic Content:	All employment by gender
Frequency:	Monthly with annual averages

Major Data Items	Detail	Area	Industry (SIC)
1. Employment, payroll, and hours	Nonsupervisory, production, and construction workers	Nation, states, and SMSAs	Up to 4-digit
2. Overtime hours	Production workers	Nation	Selected manufacturing industries

Comments

The CES survey is conducted monthly by the BLS in cooperation with the state employment security agencies. The primary data series on employment, payroll, and hours are the basis for many derived series and indexes. Seasonally adjusted data are also published. In total the CES accounts for about 2,800 national data series and 24,000 state and area series. The sample estimates are annually benchmarked to the census data from the mandatory reports of establishments covered under the state unemployment insurance (UI) laws (see the entry for the Employment and Wages Program) and other census data as necessary. Thus the data are comprehensive and consistent if the latest benchmark is utilized.

Data are collected for female employees but only for the aggregate of all employment by industry. The survey instrument does not currently provide for either the hours or earnings of female employees. The data on female employees are published at the national level. In general the level of industrial and geographical detail is lower for smaller areas. Data are available on tape in machine-readable form from BLS on a fee basis.

Data Source: Current Industrial Reports Data

Agency: Bureau of the Census
U.S. Department of Commerce
Washington, D.C.

Publication(s): Current Industrial Reports (over 100 individual industries or commodities)

Type of Data: Survey

Demographic Content: None

Frequency: Varies (monthly, quarterly, and annual)

Major Data Items	Detail	Area	Industry (SIC)
1. Shipments, inventories, orders, and exports (selected)	Sometimes in both quantity and value terms	Nation only in most cases	Up to 4-digit

Comments

The Current Industrial Reports of the Bureau of the Census provide timely data and thereby supplement the economic censuses and annual surveys of manufactures. They also provide a voluminous amount of data about specific commodities and industrial materials--from textile machinery in place to computers to machine tools to processed foods. Many of these series are not available elsewhere. Generally the data are not available on tape.

The primary limitation of the commodity data is that it is difficult to match that data with the SIC industrial codes, which are actually groups of related commodities rather than single commodities. It should also be noted that multiproduct establishments are assigned SIC codes on the basis of their major product, thus obscuring secondary products and by-products.

Data Source:	Current Population Survey (CPS) and March Supplement
Agency:	Bureau of Labor Statistics (BLS) U.S. Department of Labor Washington, D.C.
Publication(s):	Employment and Earnings, Current Population Reports, Monthly Labor Review (summaries)
Type of Data:	Household survey of about 60,000 occupied households
Demographic Content:	Age, gender, race, and education by a variety of characteristics including occupation
Frequency:	Monthly, with quarterly and annual averages

Major Data Items	Detail	Area	Industry (SIC)
1. Employment and unemployment	503 Bureau of the Census occupations	Nation, states, SMSAs, and cities	Up to 3-digit

Comments

The CPS survey is accomplished monthly by the Bureau of the Census for the BLS. The basic purpose of the CPS is to reliably estimate employment and unemployment. Other socioeconomic data, including important labor force data, are available annually by including various supplementary questions in the monthly surveys. The March Supplement, perhaps one of the most important for researchers interested in the employment effects of technological change, obtains data on income, migration, family status, occupation and industry. The CPS is increasingly used to meet the legislative requirements for distribution of federal funds to state and local areas. It is the basis for the monthly unemployment rates that are generally given wide media attention.

The CPS provides a broad array of socioeconomic data. However, it should be mentioned that this information is gleaned from a household survey and subject to errors by the respondents. As with most federal data programs, the geographic detail available is considerably less for smaller areas. Special data can be tabulated on the records of individuals in the CPS to create matched files limited, of course, to the duration of the individuals' participation in the survey.

The industrial and occupational coding in the CPS tend to be noncomparable with other data sources and over time. The new 1980 Bureau of the Census coding scheme creates a significant break in the CPS occupational time-series data. Although detailed occupational groups were statistically reestimated for the 1972-1982 period, the procedure was not judged to be accurate below broad occupational groupings or for specific age, gender, and race groupings (see Klein, 1984, in References).

A comprehensive description of the design, methodology, and technical documentation of the CPS can be found in The Current Population Survey: Design and Methodology (Technical Paper 40), available from the Superintendent of Documents. Shorter descriptions, including the most recent changes in the survey, are generally available in the publications listed in this table. Much of the data are available on tape in machine-readable form on a fee basis. See the latest edition of the Bureau of the Census Catalog.

Data Source: Economic Census of Manufactures (COM) and Annual Survey of Manufactures (ASM)

Agency: Bureau of the Census
U.S. Department of Commerce
Washington, D.C.

Publication(s): <u>Census of Manufactures</u>, <u>Annual Survey of Manufactures</u>

Type of Data: Establishment census or survey (56,000 establishments) by mail for large firms and federal administrative records (Social Security Administration and Internal Revenue Service) for small firms

Demographic Content: None

Frequency: Annual (census for years ending in 2 and 7)

Major Data Items	Detail	Area	Industry (SIC)
1. Employment and payroll	Production and nonproduction workers	Nation	Up to 5-digit
		States, SMSAs, cities, and counties	Up to 4-digit
2. Value of shipments, value-added, capital expenditures, and material costs	None	Same as above	Same as above
3. Energy costs	By type of fuel	Nation	Up to 4-digit
		States	Up to 3-digit
		SMSAs	Up to 2-digit

4. Gross assets, depreciation, retirements, and rental payments	Buildings and machinery and equipment	Nation States	Up to 2-digit All manufacturing
5. Inventories	Finished goods, work in progress, and other	Same as above	Same as above
6. Supplemental wage benefits	None	Nation States	Up to 4-digit All manufacturing
7. Location of manufacturing plants (computer tape only)	Not applicable	States, counties, and cities	Up to 4-digit

Comments

The COM and ASM are the most comprehensive source of price and quantity data about the manufacturing sector by industry. In fact, they are the sole source of some industry data such as value-added, capital expenditures, energy costs, and the gross book value of assets. However, the occupational detail is limited to production and nonproduction workers, and no information is provided about age, gender, or race of the workers. The level of industrial detail is less for smaller areas and less in the ASM than in the COM.

These data bases are voluminous, but generally a series of tapes are available from the Bureau of the Census. Technical documentation for the data are contained directly in the census of manufacturing publications series.

Data Source:	Employment and Wages Program (commonly called ES-202 Program)
Agency:	Bureau of Labor Statistics (BLS) U.S. Department of Labor Washington, D.C.
Publication(s):	Employment and Wages
Type of Data:	Virtual nonagricultural establishment census produced as a by-product of the nation's employment security programs
Demographic Content:	None
Frequency:	Quarterly reports (monthly employment data)

Major Data Items	Detail	Area	Industry (SIC)
1. Employment and payroll	UI taxable and total payrolls	Nation, states (counties by request)	Up to 4-digit

Comments

The BLS in cooperation with the state employment security agencies compiles employment and payroll data from the mandatory quarterly employer tax reports required to administer the state unemployment insurance (UI) system. These reports are a virtual census of nonagricultural establishments and one of the key sources of detailed regional data. However, it should be remembered that these data are produced as a by-product of administrative reports rather than as a direct survey. There is no occupational or demographic content available from this source.

Although the ES-202s are filed quarterly, the reporting form requires monthly data on employment for the payroll period including the twelfth of each month. Generally, an establishment is at a single physical location, but the definition of a reporting unit in the ES-202 program may differ from other federal data programs. Both the BLS and the state employment agencies publish summaries of the data, including annual averages. Depending on the specific request, the BLS may provide this data on tape in machine-readable form on a fee basis.

Data Source: Equal Employment Opportunity Data Base of Private Employers (EEO-1)

Agency: Equal Employment Opportunity Commission (EEOC)
Washington, D.C.

Publication(s): Equal Employment Opportunity Report: Job Patterns for Minorities and Women in Private Industry

Type of Data: Enterprise survey of all private firms with 100 or more employees; multiestablishment firms required to submit individual reports on all establishments with 50 or more employees plus a consolidated report; special reporting procedures for Hawaii and federal contractors

Demographic Content: Gender, race, and ethnicity

Frequency: Annual

Major Data Items	Detail	Area	Industry (SIC)
1. Employment	Nine major occupational groupings	Nation, states, counties, SMSAs, and cities with populations of 50,000 or more	Up to 3-digit

Comments

EEO-1 reports have been required of all private employers with 100 or more employees since 1966. The data are limited in occupational detail but rich in information about gender and race characteristics for those occupations. The data are available for 3-digit industries and a variety of geographic areas subject to confidentiality requirements. The EEOC is encouraging the dissemination and use of EEO-1 data. Special tabulations and requests should be directed to the EEOC.

The primary limitation of the EEO-1 data are that only private employers with 100 or more employees are required to file reports. Multiestablishment employers must report separate employment data for the headquarters unit and for all establishments with 50 or more employees (25 employees for most years prior to 1983). Thus the coverage of the EEO-1 data is less comprehensive for those industries with many small employers and/or small establishments. Coverage generally ranges from 30 percent in trade and services to 70 percent in manufacturing, transportation, communication, and public utilities. Since the EEO-1 survey is not a random sample, universe estimates for the data are not available.

There are a number of strengths in the EEO-1 data. First, it is the only data set with information about Asian Americans and American Indians. Second, it is employer-based, so the data may be more accurate than household surveys. Third, it is especially noteworthy that the definitions of the nine broad occupational groupings have not been changed since 1966. Finally, the data tend to be timely in that they are available currently through 1983.

Data Source:	Industry Wage Surveys
Agency:	Bureau of Labor Statistics (BLS) U.S. Department of Labor Washington, D.C.
Publication(s):	Industry Wage Surveys, Monthly Labor Review (summaries)
Type of Data:	Establishment survey
Demographic Content:	Some data by gender in selected surveys only
Frequency:	Irregular

Major Data Items	Detail	Area	Industry (SIC)
1. Employment, standard hours, and standard payroll	Selected occupations vary by industry	Nation and selected smaller areas	Up to 4-digit
2. Supplementary wage benefits	Health, insurance, pension plans, holidays, vacations, shift differentials, and other	Nation	Same as above

Comments

Industry wage surveys are conducted irregularly by BLS. The scope, timing, and selection of industries are determined by BLS in consultation with other federal and state agencies and private firms. Technological developments and specific user interests may affect the industries and occupations selected. The data are not generally available on tape.

The industry wage surveys provide a wealth of information on hours, earnings, and fringes for selected occupations. The surveys are too irregular to provide any time-series data, except for communications (annual until 1981) and perhaps insurance (four surveys in last 10 years). The emphasis in these surveys is clearly on the industry occupational wage levels. BLS reports that the survey error for the wage levels is 5 percent, whereas the survey error of the estimates of employment by occupation can be as high as 20 percent. Thus extreme caution must be used in interpreting the figures for occupational employment.

Data Source:	National Center for Education Statistics (NCES)
Agency:	National Center for Education Statistics U.S. Department of Education Washington, D.C.
Publication(s):	<u>Digest of Education Statistics</u>
Type of Data:	Surveys
Demographic Content:	Age, gender, race, education
Frequency:	Annual, biennial, and other

Major Data Items	Detail	Area	Industry (SIC)
1. Enrollments	By level of institution, majors	Nation, states	-
2. Educational attainment levels	By years of schooling completed	Nation	-
3. Employment and salaries	By level of institutions, faculty rank	Nation	-
4. Employment status of recent graduates	By degree, type of school	Nation	-

Comments

NCES is charged with the responsibility to collect, collate, and disseminate statistics related to education in the United States. NCES conducts many ongoing surveys, special surveys, and other activities in carrying out this mission. It also publishes selected data from other sources that relate to its primary mission. Some surveys and merged files are available on tape in machine-readable form on a fee basis. For further information see the latest NCES Directory of Computer Tapes.

The NCES data appear to have limited use in occupation-industry analysis. However, there is considerable data about teachers (including forecasts), some data about recent graduates, and various other specialized qualitative data.

Data Source: National Science Foundation's Science and Technology Funding Resources Data System

Agency: National Science Foundation (NSF)
Washington, D.C.

Publication(s): Federal Funds for Research and Development, Research and Development in Industry

Type of Data: Federal agency survey and company survey

Demographic Content: None

Frequency: Annual

Major Data Items	Detail	Area	Industry (SIC)
1. Research and development spending	By a variety of characteristics such as type of research, source of funding, sales, and employment	Nation	Selected

Comments

The National Science Foundation's federal funds survey and industry survey (conducted by the Bureau of the Census for NSF) provide data on the magnitude and trends in research and development (R&D) spending in the United States. The federal funds survey assesses the role of federal agencies in R&D spending, while the industry survey accomplishes the same goals for private industry. Although both manufacturing and nonmanufacturing are represented in the private industry survey, selected disaggregation is provided only for manufacturing. Special tabulations may be available directly from the Bureau of the Census subject to confidentiality requirements. Technical documentation for the surveys is contained in the NSF publication A Guide to NSF Science/Engineering Resource Data.

Data Source:	National Science Foundation's Scientific and Technical Personnel Data System
Agency:	National Science Foundation (NSF) Washington, D.C.
Publication(s):	Characteristics of Experienced Scientists and Engineers, Characteristics of Doctoral Scientists and Engineers in the United States, Characteristics of Recent Science/Engineering Graduates, and a variety of other publications
Type of Data:	Individual surveys with about 30,000 to 60,000 responding individuals; samples stratified by various characteristics
Demographic Content:	Age, gender, race, and education
Frequency:	Biennial for experienced scientists and engineers and doctoral scientists and engineers, periodic for recent science/engineering graduates

Major Data Items	Detail	Area	Industry (SIC)
1. Employment, unemployment, and salaries	By occupation and a variety of other characteristics	Nation	Up to 2-digit

Comments

The National Science Foundation's Scientific and Technical Personnel Data System is a rich vein of occupational, demographic, and other socioeconomic information about one component of the nation's labor force, its scientific and technical personnel. The data are published in numerous NSF publications. Of these, the most comprehensive data on minorities and women can be found in the biennial publication, Women and Minorities in Science and Engineering. Some of the data are available on tape in machine-readable form, and special tabulations may be prepared on a fee basis. For further information in this regard and technical documentation of the data, see A Guide to NSF Science/Engineering Resources Data.

The National Science Foundation supports and uses a number of data bases in developing its own surveys and statistics. For instance, the Doctorate Records File, compiled and maintained by the National Academy of Sciences (NAS) for NSF and other federal agencies, is a virtual census of doctorates awarded since 1920 and forms the basis for NSF's (actually conducted by NAS for NSF) biennial survey of doctorates. NSF also supports and utilizes the Occupational Employment Statistics of BLS and the educational statistics developed by the National Center for Education Statistics.

NSF uses its own taxonomies in developing statistical estimates. NSF totals may therefore not agree with other data sources. Researchers must be cautious in combining NSF data with other data in performing statistical analyses.

Data Source:	National Survey of Professional, Administrative, Technical, and Clerical Pay (PATC Survey)
Agency:	Bureau of Labor Statistics (BLS) U.S. Department of Labor Washington, D.C.
Publication(s):	National Survey of Professional, Administrative, Technical, and Clerical Pay, Monthly Labor Review (summaries)
Type of Data:	Establishment survey based on a suitable sampling frame
Demographic Content:	None
Frequency:	Annual

Major Data Items	Detail	Area	Industry (SIC)
1. Employment and payroll	101 skill levels within two dozen occupations surveyed	Nation	Up to 1-digit

Comments

The PATC survey is conducted by BLS, but the major components of the sampling frame such as the occupations, establishment size, and industries surveyed are determined by the President's Pay Agent--the Secretary of Labor and the directors of the Office of Management and Budget and the Office of Personnel Management. The survey covers primarily medium and large firms with the results used directly in the pay comparability process for federal white-collar employees. The occupational definitions are specifically designed to be translatable into federal occupations and may therefore differ from those in other federal and private programs. The data are not available on tape.

Data Source: Occupational Employment Statistics (OES) Survey

Agency: Bureau of Labor Statistics (BLS)
U.S. Department of Labor
Washington, D.C.

Publication(s): Occupational Employment, Occupational Outlook Handbook, and a variety of specialized publications at national and state levels

Type of Data: Establishment survey (see comments for basis of projections)

Demographic Content: None

Frequency: Three-year cycle: manufacturing, nonmanufacturing, and trade, transportation, communications, utilities, and government services

Major Data Items	Detail	Area	Industry (SIC)
1. Employment and staffing patterns and projections thereof	About 1,700 occupations	Nation, states, and selected smaller areas	Up to 3-digit

Comments

The OES program of BLS is accomplished in cooperation with the state employment security agencies. It is the major federal-state cooperative effort to estimate current and projected employment by occupation and industry. The survey encompasses about 1,700 occupations at the 3-digit level of industrial disaggregation.

The occupational employment projections are the result of a comprehensive forecasting methodology, based upon the Economic Growth Model System of BLS. First, aggregate economic performance is assessed utilizing population projections, migration data, and a vast array of economic data. Second, detailed industry output projections are prepared using an input-output model of 156 producing sectors. Third, the projections of industry employment are derived using a regression model of productivity growth by industry. Finally, the occupational employment totals by industry are obtained using the industry-occupation matrix (staffing patterns) adjusted for expected technological change and other factors.

The latest detailed BLS employment projections are contained in the BLS bulletin Employment Projections for 1995. It is worthy of note that this publication also includes the labor force estimates and other assumptions on which the economy-wide forecast is based. Summaries and updates of the employment projections usually first appear in Monthly Labor Review. The Occupational Outlook Handbook and other similar publications provide primarily descriptive material for those seeking occupational information. Subject to confidentiality requirements, special tabulations and tapes may be available directly from BLS.

Data Source: Patent Counts

Agency: U.S. Patent and Trademark Office
Washington, D.C.

Publication(s): <u>Science Indicators</u>, <u>Commissioner of Patents and Trademarks Annual Report</u>

Type of Data: Census

Demographic Content: None

Frequency: Annual

Major Data Items	Detail	Area	Industry (SIC)
1. Patents applied for and granted	55 product fields, class of owner	Nation	Selected

<u>Comments</u>

Patent counts have long been used to measure technological change with varying degrees of success. They have also been used in international comparisons of innovation and technology. Simple patent counts fail to distinguish major breakthroughs from minor breakthroughs. They are at best, a rough indicator of technological change.

Both the Office of Technology Assessment and Forecast, U.S. Patent and Trademark Office, and Science Indicators Unit, Division of Science Resource Studies, National Science Foundation, have an active interest in measures of technological progress. Researchers should contact these offices for information about the most up-to-date data, new developments, and availability and cost of machine-readable data.

Data Source:	Small Business Data Base
Agency:	Office of Advocacy U.S. Small Business Administration (SBA) Washington, D.C.
Publication(s):	<u>The State of Small Business</u> (summaries)
Type of Data:	Establishment and enterprise data constructed from private sources
Demographic Content:	None
Frequency:	Varies

Major Data Items	Detail	Area	Industry (SIC)
1. Location of establishments	Names, addresses, and phone numbers for over 8 million firms and establishments	Nation, state, cities	4-digit
2. Employment, sales, parent firm, size of establishment/firm	4.5 million firms/establishments	Same as above	Same as above
3. Detailed balance sheet data	Assets, liabilities, profits, etc. for 1.7 million firms	Same as above	Same as above

Comments

At the request of Congress in 1976 the Small Business Administration created a very large establishment/firm data base organized by size of firm. The data were constructed from private sources to allow tracking of individual establishments/firms over time without violating federal confidentiality requirements. The master establishment list contains the names, addresses, and phone numbers of over 8.1 million firms/establishments. This file was constructed from the credit reports of Dun & Bradstreet and the Yellow Pages phone listing in the Market Data Retrieval Files. Since the Dun & Bradstreet files also include key information such as employment, sales, parent firm, etc., SBA created a separate file that adds this information for all of the firms in the Dun & Bradstreet files for the years 1976, 1978, 1980, and 1982. Finally, the SBA created an annual file for 1.7 million firms from financial statements available in Standard & Poor's COMPUSTAT File and Dun & Bradstreet's Financial Statement Profile File.

The SBA data base is unique in its size and type of data available--microdata on establishments/firms by location. It is probably superior to any of the individual private sources from which the SBA data were constructed because of SBA's extensive editing and verification procedures. However, it is not a census (nor does it pretend to be) but it is nearly complete in many industries. The data base is available to the research community. Furthermore, SBA is interested in research that addresses the effects of technological change on small business.

Data Source:	Survey of Income and Program Participation (SIPP)
Agency:	Bureau of the Census U.S. Department of Commerce Washington, D.C.
Publication(s):	Economic Characteristics of Households in the United States
Type of Data:	Sample of about 20,000 households chosen to be nationally representative (scheduled to increase to 36,000 households in 1985)
Demographic Content:	Age, gender, race
Frequency:	Quarterly, beginning third quarter of 1983

Major Data Items	Detail	Area	Industry (SIC)
1. Income, labor force experience, and participation in major government assistance programs	Household longitudinal files	Nation	-

Comments

SIPP is one of the newest data series collected by the Bureau of the Census. The primary purpose of the survey is to collect data on the distribution of income and household participation in government programs ranging from Social Security to Medicaid and Food Stamps. Special reports are expected to provide data on labor force activity and history, causes and effects of labor migration, job change, health insurance coverage, and training. Given the emerging nature of this survey, it is difficult to evaluate its relevance to the study of the employment implications of technological change at this time. The SIPP data are not currently available on tape.

Data Source:	Surveys of Women-Owned and Minority-Owned Businesses
Agency:	Bureau of the Census U.S. Department of Commerce Washington D.C.
Publication(s):	Women-Owned Businesses, Survey of Minority-Owned Business Enterprises
Type of Data:	Secondary compilations from Social Security Administration and Internal Revenue Service records supplemented by mail surveys
Demographic Content:	Gender, race
Frequency:	Five years (years ending in 2 and 7)

Major Data Items	Detail	Area	Industry (SIC)
1. Number of firms, employment, payroll, and gross receipts	None	Nation	Up to 4-digit
		States, counties, SMSAs, cities	Up to 1-digit
2. Same as above	By employment-size classes, gross receipts-size classes, and legal form of organization	Nation	Up to 1-digit

Comments

The Bureau of the Census surveys of women-owned and minority-owned businesses are based on the whole firm rather than on establishments. Firms are considered to be women-owned or minority-owned if 50 percent or more of the owners are women or minorities. Corporations are classified as women-owned or minority-owned if 50 percent or more of shares are owned by women or minorities.

These data are not comparable across censuses because of definitional and other changes in the scope and method of the surveys designed to improve their coverage. These data are the most comprehensive source for enterprise statistics on women-owned and minority-owned businesses. The data are not available on tape.

Nongovernment Data Sources

Data Source: Administrative Salaries Survey

Agency: Administrative Management Society (AMS)
Willow Grove, Pennsylvania

Publication(s): AMS Office Salaries Directory, AMS Annual Guide to Management Cooperation, AMS Systems & Processing Salaries Report

Type of Data: AMS survey of member and nonmember companies

Demographic Content: None

Frequency: Annual

Major Data Items	Detail	Area	Industry (SIC)
1. Employment and wages	20 clerical and word-processing positions, 20 middle-management positions, 20 electronic data-processing positions	Nation and region	1-digit

Comments

The AMS conducts three separate annual wage surveys. The data-processing survey is newly initiated, while the office survey has been conducted since 1946 and the middle-management survey since 1972. The accuracy and completeness of these surveys are unknown.

Data Source: American Association of Engineering Societies Data Base

Agency: American Association of Engineering Societies
New York, New York

Publication(s): Engineering and Technology Degrees, Engineers' Salaries: Special Industry Report, and Placement of Engineering and Technology Graduates

Type of Data: Surveys

Demographic Content: Gender, race

Frequency: Annual

Major Data Items	Detail	Area	Industry (SIC)
1. Salaries	By position and education level	Nation	2-digit
2. Engineering and engineering technology degrees awarded	By major	Nation	-

Comments

All three sources are annual reports, although Engineers' Salaries: Special Industry Report was published biennially from 1959 to 1980. Each draws its data from large surveys of universities, recent graduates, or engineers. The accuracy and completeness of the data are unknown.

Data Source: American Chemical Society Data Base

Agency: American Chemical Society
Washington, D.C.

Publication(s): Chemical and Engineering News

Type of Data: Survey of member firms supplemented by U.S. government data

Demographic Content: None

Frequency: Annual

Major Data Items	Detail	Area	Industry (SIC)
1. Capital and R&D spending	15 companies	Nation	Chemicals
2. Total shipments and other selected financial data	100 companies	Same as above	Same as above

Comments

A compilation of association information and data from individual manufacturers and various federal sources is published annually in an issue of Chemical and Engineering News. This report includes current data along with trends from the previous 10 to 15 years. The accuracy and completeness of the data are unknown.

Data Source: American Iron and Steel Institute Data Base
Iron and Steel Facts

Agency: American Iron and Steel Institute (AISI)
Washington, D.C.

Publication(s): Annual Statistical Report

Type of Data: Private industry data from members supplemented by U.S. government data

Demographic Content: None

Frequency: Annual

Major Data Items	Detail	Area	Industry (SIC)
1. Exports, imports, total shipments, materials consumption	Selected types of steel and materials	Nation	Steel
2. Employment, hours, and payroll	Wage and salary employees, wage employees classified by age and length of service	Same as above	Same as above
3. Occupational illness/injury	None	Same as above	Same as above

Comments

AISI's Annual Statistical Report contains data from individual member companies. Each yearly edition provides current statistics plus trends from the prior 40 years. The accuracy and completeness of the individual company data are unknown.

Data Source: Annual Labor Survey of Plastics Industry

Agency: Society of the Plastics Industry (SPI)
New York, New York

Publication(s): Annual Labor Survey

Type of Data: Latest survey included 286 member companies with over 27,000 employees

Demographic Content: None

Frequency: Annual

Major Data Items	Detail	Area	Industry (SIC)
1. Employment, hours, and payroll	By job classification	Nation, region, state	Plastics
2. Unionization	Companies unionized, length of contract, names of unions involved, etc.	Nation, region	Same as above
3. Benefits and working conditions	Rest periods, sick leave, bonuses, and other fringe benefits	Same as above	Same as above

Comments

This survey, conducted annually since 1938 by the SPI, contains some unique information concerning employee wages, benefits, and unionization. More than 27,000 employees from 286 companies responded to the most current survey. The accuracy and completeness of the survey are unknown.

Data Source: Battelle Estimates of R&D

Agency: Battelle Memorial Institute
Columbus, Ohio

Publication(s): Probable Levels of R&D Expenditures

Type of Data: National Science Foundation and Battelle estimates

Demographic Content: None

Frequency: Annual

Major Data Items	Detail	Area	Industry (SIC)
1. Sources, performers, and amounts of R&D	Government, industry, university	Nation	-
2. Sources of industry R&D	-	Nation	2-digit

Comments

An annual publication since 1968, the Battelle R&D estimates provide a continuous data series from 1960 to the present. Included in the report are data on the amount of spending by source and performer for government, industry, and university R&D in both current and constant (1972=100) dollars. The accuracy and completeness of the data are unknown.

Data Source:	Data-Processing Salary Survey
Agency:	Hitchcock Publishing Company Wheaton, Illinois
Publication(s):	Infosystems
Type of Data:	Survey of 1,254 data-processing centers in 1,254 firms with over 12,000 employees
Demographic Content:	None
Frequency:	Annual

Major Data Items	Detail	Area	Industry (SIC)
1. Payroll	By selected data-processing occupations	Nation, region, selected cities	2-digit

Comments

Appearing annually in Infosystems, this survey provides a continuous source of payroll data on the selected data-processing occupations. The accuracy and completeness of the data are unknown.

Data Source: Electronic Industries Association Data Base

Agency: Electronic Industries Association (EIA)
Washington, D.C.

Publication(s): Electronic Market Data Book

Type of Data: EIA Estimates and Federal Data

Demographic Content: Gender

Frequency: Annual

Major Data Items	Detail	Area	Industry (SIC)
1. Employment, hours, and payroll	By occupational group	Nation	3- or 4-digit
2. Total employment	By production workers, female employment	Same as above	Same as above
3. Shipments	Variety of consumer and industrial electronics products	Same as above	Same as above

Comments

Combining EIA estimates with information from several federal agencies, the Electronic Market Data Book contains data on various aspects of the electronics industry. Published annually since the early 1960s, most tables show current year statistics as well as trends from selected prior years.

Specific data items of interest include total employment, female employment, workers engaged in production, average earnings and hours, and overtime hours, all by 3- to 4-digit SIC classification. R&D funding by industry group is also included. The completeness and accuracy of the data are unknown.

Data Source:	General Social Survey
Agency:	National Opinion Research Center (NORC) University of Chicago Chicago, Illinois
Publication(s):	No regular reports made by NORC since users encouraged to do so
Type of Data:	Interview survey of about 1,500 adults, 18 years of age and older, utilizing a multistage probability sampling plan
Demographic Content:	Age, gender, race, and education by a variety of characteristics, including occupation
Frequency:	Annual (some questions repeated only in alternate years)

Major Data Items	Detail	Area	Industry (SIC)
1. About 150 socio-economic characteristics and opinions	By individual	Regions	Selected

Comments

The General Social Survey has been conducted in March of each year since 1972. The questions are identical each year, and a few of the baseline questions go back to the late 1930s. The survey is currently funded through 1987.

The strength of this survey is its thoroughly eclectic approach and consistent sampling plan. Thus, trends are available on a large number of socioeconomic indicators such as income, employment, occupation, race, etc., as well as the less frequently available qualitative indicators such as financial satisfaction, job satisfaction, occupational values, etc. As in all surveys, the data are subject to sampling variability and errors of response. Obviously, the possibilities for disaggregation are extremely limited in a sample of about 1,500 individuals. These problems may be especially significant in studies of the employment implications of technological change, where disaggregated data by industry and occupation are usually desired.

NORC does not prepare regular reports on the General Social Survey but encourages social scientists to do so. The cumulative data set is available on a fee basis in printed or machine-readable form from the Roper Center, University of Connecticut, Storrs, Connecticut, along with a codebook that itemizes the survey questions. A brief introduction to the survey is available directly from NORC.

Data Source: Machine Tool Industry Data Base

Agency: National Machine Tool Builders Association (NMTBA)
McLean, Virginia

Publication(s): Economic Handbook of the Machine Tool Industry

Type of Data: Private industry and federal sources

Demographic Content: None

Frequency: Annual

Major Data Items	Detail	Area	Industry (SIC)
1. Plant and equipment investment	With machine tool share	Nation	Selected
2. Value of shipments	Type of machine	Same as above	4-digit
3. Employment, hours, and payroll	-	Same as above	Selected
4. Use of machine tools	By type and age	Same as above	Selected

Comments:

Published annually since 1969 by the NMTBA, this handbook contains various industry and federal data. The industry statistics on machine tools may be of special interest to some researchers. The handbook is nearly 300 pages in length. The accuracy and completeness of the data are unknown.

Data Source: National Longitudinal Surveys of Labor Market Experience (NLS)

Agency: Center for Human Resource Research
Ohio State University
Columbus, Ohio

Publication(s): The National Longitudinal Surveys Handbook, NLS Newsletter

Type of Data: Longitudinal survey of five cohorts--older men and women, young men and women, and youth based upon representative samples

Demographic Content: Age, gender, race, education

Frequency: Annual (with exceptions)

Major Data Items	Detail	Area	Industry (SIC)
1. Employment, payroll, and a large variety of other socioeconomic indicators, including attitudinal and qualitative variables	Varies (census occupations, work histories, family histories, etc.)	Nation (confidentiality requirements prevent release of most subnational data)	Up to 3-digit

Comments

The development of the NLS data base was initiated in 1966 by the U.S. Department of Labor under contract with the Center for Human Resource Research of the Ohio State University. The Bureau of the Census was responsible for designing and drawing the original samples and to varying degrees over the years for the survey work and initial data preparation. The sample size of the initial four cohorts, begun in 1966, is roughly 5,000 individuals for each cohort, while the youth cohort, begun in 1979, consists of just under 13,000 individuals. These are representative samples but with increased probabilities of selection for blacks to increase the reliability of the estimates for those cohorts. The industry-occupation classification system is census-based, primarily using the 1970 system.

The NLS surveys are a rich source of data on the labor market experiences of the cohorts in the sample and have been the basis for many research analyses. However, the data do not constitute a sample of the entire work force, and the size of the samples limits the number of meaningful occupation-industry cells that can be investigated. At the time of writing this report, the older men and younger men cohorts have been scheduled for discontinuance.

An excellent overview and documention of the NLS survey is provided in the <u>NLS Handbook</u>, 1983-84 edition, available directly from the Center for Human Resource Research. The handbook also details the availability of tapes in machine-readable form. Costs for tapes varies depending on the specific format, years covered, and cohorts desired.

Data Source: Panel Study of Income Dynamics (PSID)

Agency: Institute for Social Research (ISR)
University of Michigan
Ann Arbor, Michigan

Publication(s): Five Thousand American Families--Patterns of Economic Progress

Type of Data: Longitudinal survey of 5,000 families

Demographic Content: Age, gender, race, education

Frequency: Annual

Major Data Items	Detail	Area	Industry (SIC)
1. Employment, payroll, and a large variety of other socioeconomic indicators, including attitudinal and qualitative variables	429 occupations (1970 census-based), work histories, family histories, etc.	Nation	Up to 2-digit

Comments

The PSID was initiated in 1968 at the request of the Office of Economic Opportunity to assess national trends in well-being, particularly for families at or below official poverty levels. The assessment was to include economic, behavioral, and attitudinal information. Individuals are followed when they leave families, e.g., because of divorces or children leaving home, and individuals are added to the survey when they became part of an included household. That allows complete tracking of the fortunes of families but necessitates a complex sampling strategy. Suffice it to say that sample estimates of the universe remain unbiased through the use of independent subsamples and probability sampling techniques.

Clearly, detailed industry-occupation analysis is impossible with this sample, much like the NLS data. However, the broader occupational groupings can depict occupational trends over time, say, for women workers. Researchers should contact ISR for information about special tabulations and the availability and costs of tapes.

Data Source: Word-Processing Salaries Survey

Agency: Association of Information Systems Professionals
Willow Grove, Pennsylvania

Publication(s): Annual Salary Survey Results

Type of Data: Mail survey of word-processing personnel

Demographic Content: None

Frequency: Annual (since 1974)

Major Data Items	Detail	Area	Industry (SIC)
1. Employment, wages, and hours	15 word-processing positions	U.S. and Canada, major metropolitan areas	31 industries

Comments

The latest survey includes approximately 25,000 word-processing employees in over 2,500 U.S. and Canadian firms. The accuracy and completeness of the data are unknown.

A REVIEW OF EMPIRICAL STUDIES OF THE CONSEQUENCES OF TECHNOLOGICAL CHANGE ON WORK AND WORKERS IN THE UNITED STATES

Philip Kraft

SUMMARY

This review evaluates selected studies of technology and work. It is limited to recent empirical studies that have as their focus the relationship between technology and (1) employment levels, (2) skill, (3) work quality, and (4) changes in the roles of women and minorities. Although computerization and computer-based automation are the most dramatic examples of the current wave of technological change, other technologies are included where appropriate.

Technological Change and Employment Levels

In Noble's (1979) apt phrase, technology represents a social choice. More than science, it offers options with respect to ends and means. In practice it is therefore more appropriate to speak of many technologies. Because there are many technologies, it is difficult to measure, or even locate, the effects of specific technological changes on employment levels, occupational composition, occupational mobility and earnings.

In spite of these problems, studies of technology and work can raise important issues and arrive at provocative conclusions. Perhaps the most provocative are the findings of a major economy-wide study of the impact of computer-based technology on aggregate employment levels (Leontief and Duchin, 1984). The authors conclude that in the absence of other factors computer-based technologies will significantly reduce labor requirements in the U.S. economy by the year 2000. In some sectors and in some occupations the decreases will be drastic: whole occupations will disappear, while new occupations are expected to absorb only some of the displaced labor force.

Other studies of economy-wide and sectoral changes echo this finding: technological innovations have the effect of replacing labor. Although highly skilled jobs in the high-technology sector are

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expected to grow relatively faster than other jobs, at present growth rates they will provide less than 6 percent of all jobs in 1995. Most of the new jobs in high tech industries will be in traditional occupations that have lower than average earnings.

The difficulties inherent in such economy-wide forecasts are illustrated by actual trends in sectoral employment. For example, employment levels in clerical work and metalworking have reflected changing market conditions as much as computer-based technological changes. In the case of clerical work, work rationalization and automation generally accompanied market expansion and aggregate clerical employment increased (Baran and Teegarden, 1984; Appelbaum, 1984; Feldberg and Glenn, 1983). In automaking (Hunt and Hunt, 1983), in contrast, a shrinking market first reduced employment levels, then accelerated investment in robotics technologies. Hunt and Hunt anticipate that natural attrition will shield currently employed auto workers from technological unemployment, but later job seekers will confront fewer jobs as the new technologies are implemented.

In sum, the economy-wide analyses and forecasts reviewed here agree that the employment effects of technological change are uneven across industries and occupations and over time. Further, these effects are modified by other changes in the economy as a whole. In the short term, natural attrition and increased demand probably offset aggregate job losses. In the medium term, specific occupations will be eliminated and the jobs lost are expected to be only partially replaced by new jobs created by the new technologies. And the new jobs may provide lower earnings on average than the jobs lost.

Whether computer based automation will cause significant job gains or losses, then, is still an open question. What is clear is that computers and computer-based equipment will not require a large number of highly skilled, well-paid specialists. "High" technology has up to now created relatively few high-technology jobs.

Technological Change and Skill

Skill presents a different and more complex analytical problem than employment levels: there are no commonly accepted measures. As a result there is wide disagreement about the effects of technology on the creation, destruction, or enhancement of skills. In particular, although methodologically sophisticated, the reviewed studies do not resolve the issue of whether skill is an individual attribute, a characteristic of a job, or a social or collective relationship such as autonomy or control. Kusterer (1979) has pointed out that formal job descriptions--upon which most studies of skill are based--almost never adequately describe the entire range of even core tasks in a production process. Appelbaum (1984) makes a related point: analysts tend to recognize as skills only those job components managers reward. Managers usually reward formal contributions to the production process and ignore the "illicit skills" at the core of most work processes. This may explain an anomalous dichotomy in the findings of the economy-wide and sectoral studies on the one hand and case studies on the other. The large-scale studies are usually based on formal criteria such as years of education, types of training, kinds and distribution of occupations, and so on. They tend to find little or no change in overall skill levels. On the other hand, case studies of specific workplaces or occupations often stress informal working relations, which are described by no explicit criteria but are nevertheless crucial to a given production process. Case studies tend to find patterns of deskilling after the introduction of new technologies.

Nowhere is the dichotomy more evident than in white-collar work. The six studies of clerical work reviewed here generally agree that skills are created as well as lost as a result of technological innovations in the office. Of the six, only two find a net upgrading of the skills of clerical workers, although the upgrading occurs by the simple mechanism of eliminating the least-skilled workers rather than enlarging the skills of those who remain. The others see more complex consequences for the primarily female clerical work force: work that is simultaneously wider in scope and more routinized, segmented career ladders, and (possibly) lower pay.

Similar trends have been found among professional and technical workers. Even computer software specialists, the ultimate high-technology workers, have experienced a pronounced fragmentation of work accompanied by a clearly defined gender-based occupational segmentation (Kraft, 1977, 1984; Greenbaum, 1979).

If they disagree on the overall impact of technology on skill, the studies have helped sharpen an important question: should we focus on the skill impacts of automation on individual jobs, on the affected organization, or on the society as a whole? Ultimately, whatever the approach, skill should probably be approached as a political issue as much as a commodity that is acquired, lost, degraded, or enhanced. Skill may be commodity-like, but its definition is more open to negotiation than to measurement. What defines "high-skill" and "low-skill" jobs is probably as much the outcome of the relative bargaining strength of employers, employees, men, women, and majority and minority workers as it is mastery over a production technology.

Technological Change and Work Quality

Like skill, "quality of work" is a vague concept and hard to measure. The phrase has undergone a series of definitional changes. Blauner's (1964) study of work design, technology, and alienation set the terms of the discussion for a decade and prompted visions of a "postindustrial society." Braverman's (1974) analysis of the nature of skill and control has similarly framed a debate about what he called the "degradation of work." Recent concerns about Japanese management methods have informed a large literature on various forms of worker-management cooperation such as quality circles. Ironically, the rapid diffusion of computer-based machinery in the office and other white-collar workplaces has reopened a much older issue: workplace health and safety, including concerns about ergonomics and threats from radiation and chemicals.

On the whole, studies of work environment and new technology are fewer and of lesser quality than those on employment levels and skill. Why work environment in technologically advanced workplaces has received (relatively) less attention is itself an interesting issue, although beyond the scope of the present review.

Technological Change, Women, and Minorities

Of all the studies reviewed here, the most consistent findings are in the studies of the impact of technological change on women and minorities. The studies of the insurance industry and of clerical workers are in general carefully done and comprehensive. They find, with minor exceptions, that the consequences of technological change in the clerical work force have been mixed, although not ambiguous. The case studies find that office automation has eliminated (or redistributed) many of the most menial tasks in clerical work. On the other hand, responsibility has often increased without corresponding increases in autonomy or control. Opportunities for mobility have been truncated, i.e., there has been an increase in the breadth but not depth of clerical work for those women whose jobs have not been eliminated by computerization.

In office work, although average skill levels in a purely arithmetic sense rise as a result of eliminating the least-skilled clerks and data-entry personnel, channels of occupational mobility between clerical and professional/managerial jobs are being eliminated in the process. Women, especially minority women, are most likely to suffer as a result because they are most heavily represented in the low-level clerical/data-entry jobs that are disappearing. Moreover, the effects on women vary by race and class. The lowest-level clerical jobs are those with the highest concentration of women. These are likely to be eliminated, not simply deskilled (Feldberg and Glenn, 1983; Hacker, 1979). White women with higher educational levels will probably benefit the most from the upgrading of remaining clerical jobs: they will continue as a skilled if low-paid and dead-end work force, i.e., "jobs but not opportunities" (Baran and Teegarden, 1984).

Politics and Technology

Historically, changes in how we make things have generated fears about what those changes will do to jobs and the quality of work. Economists in particular have sought to calm those fears by making the argument that anything that increases productivity makes a firm or industry more competitive. When that happens, more goods and services are sold and employment rises.

This may have been true (within the limits of economic cycles), but will it hold true in the future? The introduction of computer-based production technologies is in some respects clearly an extension of a much older process of industrialization. But are computer-based technologies merely incremental changes in how our work is done?

The evidence suggests that computer-based technologies differ from earlier forms in several significant ways. Although the process of standardization encouraged the separation of management and design from production, standardization was usually limited to the physical or clerical component of traditional production processes: management, design, and service work seemed to present a "natural barrier" to standardization and mechanization. That "natural barrier" has collapsed. The current technology may not have an evolutionary nature; computerization may be the revolutionary, if logical, next step in the standardization of all work.

If modern technologies differ from their predecessors, they also share certain fundamental characteristics. They are applied primarily as labor-saving devices. They require the standardization of work as a precondition of their application. In practice, they tend to centralize, not decentralize, managerial control. In this context it is noteworthy that all of the technological innovations discussed in this review were initiated by management. All were introduced either to secure a steady supply of labor or to replace labor completely or in part. None was designed to increase labor use or to transfer control and discretion from managers to workers. Such consistency underlines Noble's caution, noted in the beginning of this summary. How science is applied to a given production process and what production process is to be the subject of technological innovation are not themselves technical questions. They are choices based on political, economic, and social criteria, not natural laws. The flexibility of technology underlines the warning made several decades ago by an early pioneer of computer-based automation: any given technology may have embedded in it a set of values that are disguised as scientific truths and inevitabilities (Wiener, 1954).

INTRODUCTION

This review evaluates selected studies of technology and work. It is limited to recent empirical studies that have as their focus the relationship between technology and (1) employment levels, (2) skill, (3) work quality, and (4) changes in the roles of women and minorities. Although computerization and computer-based automation are the most dramatic characteristics of the current wave of technological change, other technologies are included where appropriate. To be included in the review, studies must:

- measure or describe the impact of technological change on aggregate or unit employment levels, skill, job content, earnings, career opportunities, workplace relations, job satisfaction, or gender/racial differences in the workplace (new technologies are not limited to those that are computer-based);
- be based on substantial primary data or extensive reanalysis of secondary data, whether derived from aggregate or case studies;
- address issues of who is likely to benefit or suffer from the introduction of new production and organization technologies;
- use U.S. data (non-U.S. data if relevant to significant U.S. trends);
- be published after 1973.

The studies reviewed here cannot in any sense be considered exhaustive or even representative of all studies that meet these criteria. Only those that in the opinion of the reviewer clarified major issues or raised interesting new questions were included. Thus, in the final instance, the selection reflects the preferences and interests of the reviewer.

Technology and Work

Technology is the application of science to the production process. The key word here is "application." In Noble's (1979) apt phrase, technology represents a social choice. More than science, it offers options with respect to ends and means. In practice it is therefore more appropriate to speak of <u>many</u> technologies.

Because there are many technologies, it is difficult to measure, or even locate, the effects of technological change on aggregate or unit employment levels, occupational composition, or occupational mobility and earnings. Employment levels, earnings, and work environment are affected by market and product cycles, demographic changes, labor laws, and trade agreements as well as by technological innovations. The difficulties of measurement make most discussions of job content and skills largely theoretical or speculative. The same is true of attempts to gauge the effects of technological change on the work environment and workplace relations.

For this reason, expert opinion divides sharply about whether new technologies mean more work or less, lower or higher skill levels, or more or fewer jobs for women and minorities. Surprisingly, nearly all the studies reviewed here, however optimistic or pessimistic about the future of work and jobs in the United States, agree that the out- comes are not the inevitable consequences of technological change alone. In other words, none presents a variant of technological determinism; each leaves open the possibility of some deliberate intervention.

Organization of the Review

In general, this review follows the organization used by Spenner (1984), which divides studies of work and occupations into case and aggregate studies. Such a division has several advantages. Aggregate (and sectoral) studies best capture the direction of general trends and provide a picture of the economy as an interdependent whole, particularly with respect to employment levels. Case studies, which for present purposes include occupational and field studies, are more appropriate for tracking the consequences of technological changes for job satisfaction, job content, and workplace relations. They are also useful for locating and analyzing the organizational changes that usually take place before as well as after the introduction of new hardware. Case studies, in short, provide necessary reality checks on both aggregate studies and the forecasts that use them.

Case studies have tended to concentrate on two large and important industry groups: metalworking (including auto making) and banking/finance/insurance. There are good historical reasons for this emphasis. Auto making was and is the prototypical American mass-production industry. Its organization, if not its technology, remains the model for other industries, including high-technology industries. Banking, finance, and insurance are the prototypical new service industries. They also employ large numbers of women. The present review reflects this traditional emphasis but also includes studies that assess the impact of new work technologies on agriculture and computer software production. For each of the four topics selected--employment levels, skill, work quality, and the roles of women and minorities--the review covers both aggregate and case studies where both are available or one or the other as appropriate.

TECHNOLOGICAL CHANGE AND EMPLOYMENT LEVELS

Aggregate and Sectoral Studies

Employment levels reflect multiple and often contradictory forces, only some of which are technological. For example, the recent history of the metalworking industries encompasses not only robots but shifts in consumer preferences, "voluntary" export restrictions, and differing management-union relations in Japan, Europe, and the United States. We may have to confront the possibility that we are not yet capable of making accurate large-scale assessments or projections about technology and employment. Nevertheless, several noteworthy attempts have been made, with provocative results.

The most ambitious of the aggregate studies was that undertaken by Leontief and Duchin and their colleagues (1984) with support from the National Science Foundation. Leontief and Duchin project the effect of computers and computer-based automation on employment in 53 occupations. Using an input/output model, they derive the employment consequences of automation by looking at the effects of technological change on investment. Their three forecasts are based on actual changes between 1963 and 1980 and evaluations of industry projections of anticipated technology demands. The forecasts differ chiefly in their assumptions about the rate of technological diffusion.

For the most part, computer-based technologies are labor-saving strategies; other considerations are secondary. For example, in the case of robots (Leontief and Duchin, 1984:4.20-4.21), up to now they:

> . . . have been [used] primarily to replace unattractive and often dangerous jobs in foundries and in welding and painting operations in auto and farm equipment assembly plants. Far larger labor impacts await the introduction of more sophisticated machine loading and assembly robots. . . . While concerns over reliability and accuracy in the performance of work tasks and over the health and safety of workers may affect the decision to invest in robots, the overwhelming determinant is reduction of labor costs.

Leontief and Duchin's main finding is that 10 percent less labor will be required by the year 2000 to produce the same goods and services as those produced in the absence of automation. The effects will be uneven: the number of professionals will increase while the number of clerical workers will decline steeply. Some industrial jobs will disappear while a smaller number will be created as a result of increased demand for capital goods.

Technological change will affect a broad spectrum of industries and occupations. Service and financial industries will be further automated, affecting more clerical, professional, and managerial work. Typists, secretaries, stenographers, and office-machine operators will be affected by both word-processing equipment and so-called integrated office systems. Bank tellers, telephone operators, cashiers, retail establishment clerks, and even traveling salespeople will be similarly affected. Leontief and Duchin also foresee rough times for middle managers.

The automation and computerization of manufacturing industries will continue, primarily as a result of robots and computer-numerically controlled (CNC) machines. Although some growth will occur in occupations directly related to the design, operation, and repair of the new technologies, those jobs will not be enough to replace all the jobs eliminated, such as drafting, or compensate for the drastic reduction in the number of others, including machining jobs.

Although the Leontief and Duchin study has only recently appeared, it has already provoked wide response, ranging from admiration of its scope to a general skepticism of the utility of economy-wide projections, particularly given the track record of earlier efforts.

Rumberger and Levin (1984) object to the absence in the model of any way to account for changes in productivity and employment levels caused by nontechnological factors. Hunt and Hunt (in this volume; see also 1984) criticize Leontief and Duchin on several technical grounds and question fundamental assumptions about the diffusion of specific technologies (robotics and desktop computers). They also note that the employment forecasts are "artifacts" of the input/output model and therefore subject to the quality of the authors' judgments about specific industries, technologies, and occupations. Furthermore, they point out, computer-based technological change is the only type of technological change considered.

To these may be added reservations about other general and specific assumptions made by Leontief and Duchin. The relationship between the appearance of a technological innovation and its diffusion is mechanistic. If a technology exists, Leontief and Duchin seem to say, it will be used. Their three matrices differ in the rate of diffusion, but offer no discussion of what factors promote or inhibit the use of a given technology in a given industry or occupation. For example, there is no mention of the emergence of clerical trade unions, or of employers who decline to use a particular technological innovation because it will alter management/worker relations. Both may retard the use of particular technologies (see the discussion of Friedland, Barton, and Thomas, below).

Leontief and Duchin hold an equally mechanistic view of the relationship between automation and productivity. For example, they expect that voice-activated typewriters "can save 100 percent of the time required to produce a typewritten document" (Leontief and Duchin, 1984:5.17). Although they acknowledge that estimates about reduced labor needs must take into account an increase in the demand for text processing, they do not describe the relationship between voice-activated typewriters, word processors, and integrated office systems, nor, for that matter, the dynamics of office work.

Leontief and Duchin limit their definition of computers to those that need tending by computer specialists. They also expect the installed based of computers to peak in 1990. Both assumptions seriously understate the probable effect of computerization. Powerful microprocessor-based desktop machines can now be operated by nonspecialists. Desktops dispense with the services of not only computer specialists but of several layers of middle managers, supervisors, professionals, clerks, and typists. Although Hunt and Hunt (1984) are correct that early industry projections about desktop sales have not held up, a continuing and wide diffusion of this technology is likely, if not always in forms we know now.

Finally, the most dubious assumption of all: "[W]e distinguish only between those tasks which can be automated and those that cannot . . ." (Leontief and Duchin, 1984:5.19). In assessing the effects of computerization on the production process, Leontief and Duchin exclude "future breakthroughs [and] the commercial use of technologies which have not yet been effectively utilized, but we do assume the incremental improvement of currently available technologies" (Leontief and Duchin, 1984:4.3). This is both prudent and unrealistic: prudent because it makes little sense to predict the effects of nonexistent technologies, unrealistic because it makes even less sense not to anticipate the same rapid pace of technological innovation we have experienced in the last 30 years.

The root of these and similar criticisms is that the Leontief and Duchin model, like all economy-wide forecasts, is limited by the forecaster's ability to incorporate a staggering range of knowledge about specific industries and technologies. Relying on "expert opinion" is problematic because the experts disagree, especially about new technologies. Leontief and Duchin variously over- and understate the likely diffusion of particular technologies; the complexity of their model makes it difficult to gauge what assumptions need to be changed or qualified.

In spite of these criticisms, the Leontief and Duchin study is the most elaborate effort of its kind. Its conclusions, although heavily qualified by the authors, suggest that in the absence of other factors computer-based technologies will significantly reduce labor requirements in the U.S. economy by the year 2000. In some sectors and in some occupations the decreases will be drastic: whole occupations will disappear while new occupations will absorb only some of the displaced labor force.

Other studies of economy-wide and sectoral changes echo many of Leontief and Duchin's major conclusions: technological innovations have been used, and will continue to be used, to reduce labor costs. Some jobs have been lost, others created, and employment levels have changed.

In a series of related papers Rumberger and Levin have used Bureau of Labor Statistics (BLS) data and projections to examine the fastest- and slowest-growing occupations. Their analysis of BLS data is useful because it forces us to examine fashionable terms like "high technology" and to be cautious in our assessments of the employment potential of the new technologies. Their emphasis differs from the Leontief-Duchin forecast in that they stress the kinds of jobs created or lost, i.e., "high-tech" or traditional jobs.

In 1980 only about a quarter of the jobs in what BLS defines as high-tech industries (using a combination of R&D expenditures and proportion of "technologically oriented workers" as criteria) meet the BLS definition of high tech, in this case, jobs having an understanding of the principles and theories of science, engineering, and mathematics. The rest were traditional (and poorly paid) jobs in warehousing, assembling, and so on. Although high-tech jobs are expected to grow relatively faster than other jobs, they will provide less than 6 percent of all jobs in 1995 at present rates. Most of the new jobs in high-tech industries will be in traditional occupations with less than average earnings (Rumberger and Levin, 1984:17-22). Rumberger (1984) uses the same data to argue that technological innovation is likely to replace old low-paying jobs with new low-paying jobs and eliminate some high-paying jobs as well. The fastest growing jobs in absolute terms will continue to be poorly paid and dead-end, e.g., cleaning, food serving, etc.

The Office of Technology Assessment (OTA) of the United States Congress (1984) has published a comprehensive analysis of programmable automation in manufacturing. The report reflects the influence of a large and diverse staff and advisory committee and therefore presents some problems with methodological consistency from section to section. However, with respect to employment levels, the report arrives at conclusions similar to those of Leontief and Duchin: programmable automation equipment displaces labor in manufacturing. Blue-collar workers are most likely to be displaced while the majority of newly created occupations are likely to go to engineers and other white-collar workers. The authors see the displacement effects mitigated by a slowing in the growth rate in the work force, the uneven and imperfect diffusion of existing technologies, and shifts in sectoral employment.

In a more narrowly focused study of manufacturing industries, Levy et al. (1983) found that for the auto, steel, coal, iron, and aluminum industries all except steel underwent substantial technological change between 1958 and 1977. The major goal for the new technologies was to save labor costs, and all saw a displacement of labor, much of which was due to nontechnological factors. Job losses were offset by increases in demand and by quits and retirements. The authors see the offsetting trend continuing.

Levy et al. did not include the effects of robots in their analysis, which covered a period when robots were not a significant investment. In a footnote (Levy et al., 1983:17) they dismiss current robotics investments in the auto industry as a "drop in the [capital] bucket." A later paper by Levy and Jondrow (1984) extends the analysis to 1980 for steel and autos and makes essentially the same point.

The neglect of robots is a serious gap in otherwise impressive studies. Recent developments in both auto and steel, described in the Office of Technology Assessment study, may force Levy and his colleagues to qualify their position. Robots, like computer-based technology in general, are introduced to save labor and extend management control.

Hunt and Hunt (1983) also reach different conclusions about the employment consequences of robots. On the basis of current growth rates in the use of robots, Hunt and Hunt project that robotics will create between 32,000 and 64,000 jobs and eliminate between 100,000 and 200,000 jobs by 1990, of which 30,000 to 50,000 of the lost jobs will be in the auto industry alone. About half the new jobs created by robotics will be for engineers and technicians. Present workers are likely to be unaffected because of normal turnover (quits and retirements), but future workers in the auto and other industries will confront fewer job opportunities, primarily in welding, painting, and assembly.

For Hunt and Hunt the diffusion of robotics is an evolutionary rather than revolutionary development of existing industrial technologies. Robotics are important, but the effects are long-term. The authors repeat two of the central themes found in most of the economic literature: the effects of the new production technologies will be uneven, and their impact on overall productivity levels will be more important than their direct effect on employment levels. In essence, say Hunt and Hunt, the overall efficiency and competitiveness of industries and the economy as a whole are what matters for employment levels, not particular technologies.

Feldberg and Glenn (1983) also note the uneven and sometimes contradictory employment patterns that follow the introduction of new technologies, in this case office automation equipment. Their analysis of census data shows that computer specialists of all kinds grew rapidly, as expected, and noncomputer machine operators disappeared, also as expected. However, receptionists and typists continued to grow, and secretaries--who were expected to be displaced--grew at a faster rate than the clerical work force as a whole. The authors suggest that structural changes in the economy played at least as important a role in clerical employment patterns as technological innovation.

The aggregate employment figures are less interesting to Feldberg and Glenn than are patterns of occupational segmentation. Specifically, technological innovations in white-collar work have affected men and women differently: jobs that have been eliminated are held primarily by women while the new layers of (relatively fewer) jobs being created go primarily to men.

In sum, aggregate-level analyses and forecasts agree that technological innovations are introduced primarily to replace labor. The effects so far have been uneven and, as the clerical data indicate, modified by structural changes in the economy as a whole. In the short term, natural attrition and increased demand probably offset aggregate job losses. In the medium term, specific occupations will be eliminated and only partially offset by new jobs created by the new technologies. On the whole, the new jobs are likely to provide lower earnings than the jobs lost.

Case Studies

Although the case studies reviewed here focus primarily on skill and mobility opportunities, two also address employment levels in specific organizations and industries.[1]

Insurance

Using BLS industry data and interviews with workers in several insurance companies and agencies, Appelbaum (1984) found that in the early stages of computerization in the 1960s employment in insurance increased at a faster rate than both the economy as a whole and insurance industry output. However, the rate of increase in employment dropped sharply in the 1970s and continues to do so. Furthermore, employment growth has moved to the periphery of the insurance industry: agencies and brokerages saw the greatest increases, insurance providers the least.

Between 1970 and 1978 there was also a dramatic increase in the percentage of management employees. Appelbaum sees this as title inflation reflecting the price inflation of the 1970s as well as the result of affirmative action pressures.

Between 1973 and 1978 aggregate industry employment levels grew slowly while industry output continued to expand. This time, lower-level professionals were affected (Appelbaum, 1984:36):

> To some extent, the deskilling of underwriting and rating positions in personal [life insurance] lines may show up as an increase in the number of machine operatives. . . . Of course, some firms retained the underwriter designation for what had become a routine clerical job. This makes it difficult to interpret the relative decline in the share of clerical workers.

The most drastic changes in job design came after 1981 (Appelbaum, 1984:21):

> The job of rater was soon eliminated while that of underwriter, which had been a professional job requiring a knowledge of insurance and decision-making . . . was . . . transformed into a routine clerical task. In upwards of 80 percent of the cases in personal-lines underwriting the underwriting decision is made by the computer.

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[1]It is hard to tell how representative these and the other reviewed case studies are. Few of the authors of the case studies describe the criteria for selection of either the organization, occupation, or respondents. Generalizations, therefore, are problematic. On the other hand, the purpose of case studies is not generalization, but analysis of social relations.

Lettuce and Tomato Production

Friedland et al.'s (1981) study of the California lettuce and processing-tomato industries is especially important in the present context because it is one of the few studies of agricultural technology and because it examines the effects of technological innovations that were not computer-based.

Friedland et al. compare the different patterns of mechanization of processing tomatoes and lettuce in California during the 1960s and 1970s. Growers of both crops depended heavily on a predictable supply of migrant labor. Much of the migrant labor was from the *bracero* program, which was scheduled to end in the mid-1960s. The different responses of the tomato and lettuce growers to an imminent labor shortage is relevant to some of the assumptions about the diffusion of technology discussed earlier. In the case of processing tomatoes, the growers accelerated development of both a new tomato harvesting/sorting machine and new tomato varieties to go with it. The machines were expensive and suited only to large-scale operations. The results were massive reductions in the number of tomato workers: from 50,000 in 1962, before mechanization began, to 18,000 in 1975, when virtually all processing tomatoes were mechanically harvested (Friedland et al., 1981:109).

There was an even more dramatic decline in the number of tomato producers, from about 4,000 in 1963 to 600 in 1973. Those 600 producers harvested considerably greater tonnage from more acres than did the 4,000 producers in 1963. Thus, small producers as well as employees were drastically affected by the new technology. At about the same time tomatoes became a year-round national commodity, exacerbating the trend to concentrate the industry by eliminating small regional producers whose markets had been local and seasonal.

In contrast to the tomato producers, the lettuce growers began a search for alternative sources of labor. They have adjusted by relying on varying mixes of "green carders," undocumented workers, and local workers in place of the *braceros*. Although elaborate mechanical and chemical technologies (including x-ray-based harvesting machines) were being developed, experimentation stopped once the new labor supply was secured. There have been several important technological improvements in lettuce planting and harvesting, but, in contrast to the radical transformation of tomato harvesting, they have been incremental and evolutionary. The effect on employment levels has also been less drastic (Friedland et al., 1981:70ff), although lettuce production has undergone further concentration.

Friedland et al. conclude that the different rates of technological innovation in two major agricultural commodities have been conditioned by labor market considerations rather than by any inherent superiority of new technologies or traditional labor-intensive methods of harvesting. The organization of lettuce and tomato production, in other words, is driven by the (labor) market, not by technology.

TECHNOLOGICAL CHANGE AND SKILL

Skill presents a different and more complex analytical problem than employment levels: there are no commonly accepted measures. In the last 30 years the emphasis has shifted from mastery over a set of tasks (Bright, 1958) to autonomy (Blauner, 1964) to the integration of conception and execution (Braverman, 1974) to formal or informal control over work and task decisions (Kusterer, 1979; Albin, 1984). In addition, the "human capital" school has tended to identify skill with formal education and training.

The shift in definition mirrors a growing awareness that "skill" is not only a fixed attribute of individuals. Insofar as it involves issues of judgment and control, skill is both a social and political category. "Objective" measures of task mastery assume that those who define the tasks and measure their mastery know what the relevant tasks are and what constitutes various levels of competence. Kusterer (1979) has pointed out that formal job descriptions almost never adequately describe the entire range of even core tasks in a production process, including the most standardized. It is often necessary to use workers' "illicit," that is, unrecognized, skills to get the job done even when they are explicitly forbidden by production engineers. Appelbaum (1984) makes a related point: analysts tend to recognize as skills only those job components that managers reward. Managers usually reward formal, not informal, contributions to the production process and ignore the "illicit skills" at the core of most work processes.[2]

Aggregate Studies

Spenner (1984) variously defines skill as the "requirements of occupations" or "mastery of substantive complexity and autonomy." His extensive review of aggregate and case studies of occupational skill suggests to him that it is not yet possible to determine whether skills have increased or declined. Aggregate data point to overall stability of skill, although specific occupations and industries have shown a tendency toward deskilling. He concludes that skill changes have been uneven, offsetting, and not attributable to any one cause, including technology. This lends support to what he calls a "mixed change" effect, as distinct from deskilling or skill-upgrading arguments.

The authors of the OTA (1984) study of manufacturing industries reach a different conclusion, at least in part. They define skill as an individual attribute with two components: depth (mastery over a set of related tasks) and breadth (mastery over a set of unrelated tasks).

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[2]Albin and Bahn (forthcoming) have attempted to model job content, complexity, and autonomy in machining jobs on the components of a hypothetical computing machine. Their major assumptions are essentially those of traditional scientific management, however, and therefore subject to the objections of Kusterer and Appelbaum.

Programmable automation technologies reduce the depth component of skills of manufacturing workers but in at least some cases they have increased the breadth.

Case Studies

Clerical Work

New production technologies generate multiple and contradictory consequences. Nowhere is this more evident than in clerical work. The six studies of clerical work reviewed here generally agree that skills are created as well as lost as a result of technological innovations in the office. Of the six, only Adler (1983, 1984) and to a lesser extent Baran and Teegarden (1984) see a net upgrading of the skills of clerical workers, although the upgrading occurs by the simple mechanism of eliminating the least-skilled workers rather than enlarging the skills of those who remain. The others see more complex consequences for the primarily female clerical work force: work that is simultaneously wider in scope and more routinized, as well as segmented career ladders and possibly lower pay.

Adler (1983, 1984) analyzes "the requirements of effective management," particularly with respect to understanding the skills required by new computer-based technologies in banks. Explicitly contrasting his approach to Bright's (1958), Adler focuses his concept of skill on worker responsibility, cognitive learning, and job interdependence rather than mastery of a fixed set of tasks (Adler, 1983). His data are from a large French bank, including two months' participant observation as a teller, and from aggregate data on U.S. and French bank workers.

Managers are attracted by both the labor-saving potential of automation and the chance to replace skilled labor with unskilled. However, Adler cautions that the skill displacement is illusory; his research indicates that the opposite will happen. There is "peripherization": "[E]mployees have been pushed from the center of the accounts fabrication process to the periphery of a powerful automatic system . . ." (Adler, 1984:14). The result is neither a traditional pyramid-shaped organization nor the "hourglass" currently discussed in the organizational literature, but a spherical shape. Because the jobs eliminated are the least skilled, the overall effect is to upgrade the skill requirements of the remaining bank jobs. The result is an increase in the levels of "responsibility, abstractness, and interdependence" of the bank workers who are left.

Adler bases his argument on what he describes as an increase in General Skill levels (Bright's fourth component of skill), the evidence for which is the bank's development of educational courses and video cassettes (Adler, 1983:24), although he is unclear for whom the new educational courses are intended. Adler acknowledges that the more responsible and abstract jobs are "boring." Furthermore, many of the new jobs are more closely monitored and evaluated than ever and are probably responsible for increasing job dissatisfaction.

It is difficult to evaluate many of Adler's conclusions. In general, when Adler refers to low-level bank workers it is not clear if he is talking about clerks, tellers, machine operators, supervisors, data-entry people, or even managers, programmers, or auditors. The spherical organizational shape is conceptually vague; it is deduced from his analysis of peripherization rather than from an analysis of detailed job categories and content of the remaining jobs.

When Adler says that the average skill levels of the remaining workers are increased because computerization eliminates the least skilled jobs, he begs an important theoretical question: can we assume that changes in the level of organizational technology have parallel consequences in the skill requirements of particular jobs in that organization (see Feldberg and Glenn, 1983)? He also sidesteps an important practical question: what happens to all workers affected by computerization, not just those who keep their jobs? It is an issue Adler explicitly declines to discuss.[3]

Adler's findings that microprocessor-based automation eliminates only low-skilled clerical jobs, thus raising the overall skill levels of the remaining jobs, are only partly supported by the research of Feldberg and Glenn (1983), Appelbaum (1984), and Baran and Teegarden (1983). In their study of customer service clerks in a utility company, Feldberg and Glenn (1983) found that computerization increased the "scope of information" for which the clerks were responsible but also placed them under closer supervision, intensified their labor by reducing "slack time," and reduced the amount of knowledge they needed to perform their more rationalized jobs. In some respects clerks had more autonomy, in others less.

Appelbaum (1984) explicitly responds to Adler's claim that skills increase rather than decrease when clerical and data-entry jobs are computerized. Her data are from several insurance companies and agencies in New York, Pennsylvania, and California. She also uses aggregate data for the industry as a whole. In particular, she is interested in "the deployment of new equipment and the design of jobs."

According to Appelbaum, more business is being done with fewer employees. Jobs are being redesigned to collapse professional and clerical functions. The least skilled positions are being eliminated,

[3] The exception is a reference to the historical tendency of employment levels toward equilibrium (Adler, 1983). Some of Adler's most interesting observations about office automation, although not substantiated by detailed data from his bank study, suggest important developments. For example, automation reduces the overall number of errors in a banking transaction, but the errors that are now committed are doozies. They are not only more expensive but potentially disastrous for the whole system. Moreover, "[w]hen system efficiency requires that workers do not merely put in 'a fair day's work for a fair day's pay,' but instead take responsibility for the quality of that output, something profound has changed in the very nature of the employment relationship" (Adler, 1984:26.7).

old skills are being augmented, but not replaced, by technological innovation, and traditional career ladders are disappearing. Recent job design has (Appelbaum, 1984:22ff.)

> . . . included both the integration of tasks into multi-activity jobs and the elimination of the lowest level clerical and less skilled professional jobs. The resulting configuration of jobs varies from firm to firm, but in every case job categories have become abruptly segmented while the avenues of mobility between them have been sharply reduced. . . . Yet, these very jobs are less fragmented, less centralized, involve considerable training, and often require a greater knowledge of the product than the jobs that have been replaced. . . . [The] gap between the skills of clerical workers and those of professionals has widened despite the elimination of unskilled work . . . . Skill requirements for clerical workers have increased at the same time that the jobs have become increasingly dead-end.[4]

Appelbaum concludes that technology is only one factor in a larger equation in the relations of the workplace. The introduction of computers merely intensified and extended the standardization and fragmentation of work that were already well established, a process Appelbaum identifies with deskilling. Well before computers were introduced in the 1960s and 1970s "the production process [in the insurance industry] had already been rationalized. . . . Jobs were fragmented and functionally specialized, and paper wended its way around the office floor just as surely as if it were on an assembly line." The transition was further intensified by the shift from batch to on-line computing. Some low-level underwriting tasks were automated and assigned to machines and clerks. There was a corresponding increase in the number of female underwriters. The process was later extended to policy issuance, claims processing, payments, and sales, and is now being extended to "decision support systems" and to communications with external data bases or high-volume agents with in-house microcomputers.

In their study of an insurance company, Baran and Teegarden (1984) arrive at conclusions similar to Appelbaum's. Their focus is the interplay between job design and the availability of cheap, well-educated female labor for a rapidly changing insurance industry.

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[4]Appelbaum notes that Bright's categories of skills--upon which such diverse researchers as Adler and Braverman have built their analyses--identify only those job components for which employers compensate workers. This approach, she says, ignores "the importance that the particular job makes [sic] to the overall functionality of the organization. This is what allows executive secretaries to be paid less than their bosses, and city child care workers to be paid less than dog pound attendants. The skill content of key jobs in an organization are in this way systematically devalued." The workers who lose most by this systematic devaluation are women.

Baran and Teegarden divide the automation of work in the insurance industry into stages: the first stage automated (via computers) those highly structured tasks already characteristic of the industry. At this point, the process more or less follows the taylorist logic described by Braverman (1974). The second stage reflects more sophisticated technologies <u>and</u> new market conditions--namely, the availability of cheap, well-educated female workers and a highly competitive market that demands both standardized and flexible products (Baran and Teegarden, 1984:12ff.):

> . . . [The] explosion of clerical categories in aggregate data on the insurance industry--as well as increasing levels of differentiation within these categories--is evidence of the rationalization of production . . . approaches to the problem of automation have changed as dramatically as the machines. This evolution can be characterized as the gradual movement from functional approaches to systems approaches, that is, from automating discrete tasks . . . to rationalizing entire procedures . . . to reorganizing and integrating all the procedures involved in a particular division, product line, or group of product lines . . . automation follows the new logic of the organization; older functions may not be automated but simply eliminated as artifacts of an outmoded production process. . . . Even in less sophisticated systems, functional divisions are being eliminated.

The work process is in this respect being reintegrated, but (Baran and Teegarden, 1984:19)

> the kind of electronic integration of work we have just described is not synonymous with greater worker autonomy and responsibility . . . decision-making has been closely circumscribed . . . although this labor process is a far cry from the assembly line, Taylorist logic has not been entirely superseded. Higher level functions are being automated and turned over to cheaper labor.

Murphree's (1981, 1984) case study of legal secretaries shifts the focus to an elite group whose jobs and status set them apart from most other clerical workers. Her data are from participant observation in a single, large (500 employees, including 225 lawyers) Wall Street law firm, a survey of 59 of the firm's 107 private secretaries, and interviews with lawyers, other secretaries, and experts. She is especially concerned with the changes in traditional authority, rewards, and task structures as a result of organizational and technological change, specifically specialization and word processing.

Murphree's law firm was organized into 13 nonlegal departments ranging from messenger services to paralegals to word processing, accounting, filing, proofreading, and reprographics. A fast-food firm was subcontracted to make the coffee. In short, the work of the legal secretary had been thoroughly rationalized and bureaucratized.

Legal secretaries have had their jobs freed from menial or boring tasks such as duplication, coffee making, and greeting visitors and clients. In this respect their status has been enhanced within what Murphree calls the nonlegal caste. On the other hand, office automation has also eliminated the need for their stenographic skills, and they have lost their responsibilities for paralegal work, which is now being turned over to yet another specialized group of employees. The latter are also women but better educated and more like the attorneys in terms of social class. Murphree stresses the "market-driven," as opposed to technological, basis of this loss of job responsibilities: when legal secretaries wrote boilerplate wills or did legal research, their time could not be billed to the client. The time spent on the same tasks by paralegals (who are paid less than secretaries) can be billed at a rate close to the attorney's.

Legal secretaries are confronted with contradictory pressures as a result of organizational and technological change, some of which they find positive, others negative. They like the support services, especially word processing, but miss the challenge of doing the paralegal work and using their stenographic skills.

In spite of the fragmentation of tasks, legal secretaries remain important precisely because they perform nonroutine tasks that require an intimate knowledge of their organization's structure and their boss's habits and preferences (Murphree, 1984). In short, the legal secretary's relationship to her boss remains patriarchal, her main role emotional rather than technical.

The secretary as gatekeeper and managerial status symbol is also the focus of Machung's (1983) study of "the transformation of authority and control that have occurred in the clerical labor force due, first to the feminization of that labor, and secondly to its automation." Machung's study is based on her experience as a secretary and interviews with a snowball sample of 41 secretaries, word processors (her term), and supervisors. Secretaries, and their predecessors, stenographers and typists, have always been women,[5] even when other clerks were men. Being a secretary is therefore not only prototypical clerical work, it is prototypical women's work (Machung, 1983:174ff.):

> . . . if the invention of the typewriter and the feminization of the office represents [sic] the first major transformation of clerical work in this country, the introduction of word processing technologies and the automation of the office represents its second major transformation . . . while many vendors are very excited about the potentialities for automating management, much of the technology now selling on the market is directed at the clerical labor force.

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[5]Machung is mistaken on this point. Until the turn of the century secretaries and their occupational cousins, corporate clerks, were primarily men.

From her interviews with word-processor clerks, Machung says the machine skills needed to operate word-processing equipment are fewer than those required by a typist. Decision-making algorithms are now built into the machine, reducing the need for discretion and judgment. Machine skills are not the same thing as computer skills. Being a word processor, according to Machung, does not require spelling skills or even the conventional keyboarding skills of a traditional typist.

Why, then, do so many word processors claim that they have learned new skills and love their jobs? Word processors, denied the usual interpersonal gratification associated with traditional secretarial work, look for extrinsic gratification: flexible hours, slightly higher pay, etc. Machung quotes a supervisor who says the work is so boring that she has to fire operators after two or three years because they become stale and burn out. They have also become relatively expensive as well as dissatisfied, increasing management's incentive to replace them with younger, fresher, and cheaper workers.

Above all, word processing eliminates "the need for fundamental interpersonal skills." This is the greatest threat to secretaries, if not typists. In fact, the central component of clerical work according to Machung is not technical labor but emotional labor. Focusing on technical deskilling misses the point that clerical work was designed to make use of supportive "female" qualities: "At the heart of secretarial labor, in sharp contrast to both blue collar and professional jobs, is emotional labor--creating a good working relationship with one's boss and displaying a good attitude toward one's job." The diplomatic and other social skills considered essential for the good secretary are the same skills considered essential to the good manager and executive; the difference is pay and power. Machung calls this the "capitalization of courtesy." Although the job is defined by technical skills (typing speed, for example), actual hiring is usually based on what Machung calls invisible--and unrewarded--emotional labor. This may explain why the dramatic increases in clerical productivity claimed by word-processing vendors have failed to materialize (an observation, however, Machung makes without supporting evidence). "Deskilling" is therefore insufficient and probably inappropriate to describe the transformation of clerical work.[6]

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[6]The thrust of taylorism, say Machung, was not only to cheapen labor by deskilling it, but to destroy craft culture and solidarity by destroying apprentice programs. This applied almost exclusively to men. The corresponding pressure to deskill traditionally female jobs was less intense: women's wages were already low and they controlled no apprentice programs and created no culture of control. Managers already exercised control over cheap female workers via patriarchal relations and until recently there had been no cost or control incentives to apply taylorist techniques or high-tech machinery to their work relations. In effect, the feminization of clerical work retarded its rationalization.

Computer Software Workers

The Kraft and Dubnoff studies (Kraft and Dubnoff, 1984; Dubnoff and Kraft, 1984) of computer programmers analyze the effects of organizational, i.e., managerial, innovations in a high-tech occupation. They are based on structured interviews with a probability sample of 667 computer software specialists stratified by gender and age. The focus of both studies is task distribution, authority relations, and earnings, with emphasis on gender differences.

Ironically, this prototypical high-tech work was simplified and standardized in the absence of breakthroughs in software production technology. After an initial period of master-apprentice organization, software production was reorganized along conventional bureaucratic lines. The management incentive expressed explicitly in industry literature was to transfer responsibility for software design and implementation from technical specialists to management specialists and to reduce dependence on scarce highly skilled labor (see Kraft, 1979; also Greenbaum, 1979).

Analysis of the overlap of time spent on tasks showed a clear-cut division between clusters of generalist managers, systems analysts (designers), programmers and coders, and a group whose major job is mediation and support, e.g., client relations, manual writing, in-house educational programs, etc. There is no significant overlap in the performance of tasks: management specialists spend little or no time engaged in the technical work of designing, writing, or testing computer programs, while technical specialists have little say in decisions about the workplace or management of the organization. Similar divisions exist within technical clusters (Kraft and Dubnoff, 1984).

TECHNOLOGICAL CHANGE AND QUALITY OF WORK

Like skill, "quality of work" is a vague concept and hard to measure. Like skill, too, quality of work has undergone a series of changes in definition. Blauner's (1964) study of work design, technology, and alienation set the terms of the discussion for a decade and prompted visions of a "postindustrial society." Braverman's (1974) analysis of the nature of skill and control was also a discussion of what he called the degradation of work. Recent concerns about Japanese management methods have informed a large literature on various forms of worker-management cooperation such as "quality circles." In addition, the rapid diffusion of computer-based machinery in the office and other white-collar workplaces has reopened a much older issue: workplace health and safety.

Aggregate Studies

Dubnoff (1978) uses ratings employed by the 1965 Dictionary of Occupational Titles to measure shifts in what he calls the quality of work. The DOT rates each of its detailed occupations high or low on five characteristics: (1) General Educational Development, (2) Specific Vocational Preparation, and involvement with (3) Data, (4) People, and (5) Things. Dubnoff applies those ratings to the occupational distribution in every decade between 1900 and 1970. The results are ambiguous, in part because of the massive shift out of agricultural occupations, which the DOT rates low on most measures. If agricultural and nonagricultural occupations are combined, there is a decrease in complexity of work with data and things, while work with people rises slightly. There is a shift toward the middle ranges of vocational training requirements rather than a move up or down. General Educational Development increases.

If the nonagricultural sector is analyzed by itself, there is not much change. Dubnoff concludes that because the method is biased in favor of increasing work quality (the DOT seriously underestimates the nature of agricultural work), the lack of clear-cut evidence of such a trend among the nonfarm labor force indicates that the overall quality of work as he measures it has not improved in this century. Dubnoff cautions that his analysis says nothing about intraoccupational changes during the period, i.e., changes in the content and work relations of specific occupations.

The Office of Technology Assessment report cited earlier notes that manufacturing workplaces are often cleaner and quieter after the introduction of programmable automation systems. Ironically, if traditional manufacturing workplaces are becoming safer and quieter, office automation may be increasing occupational hazards for clerical workers, for example, low-level radiation generated by computer terminals and chemical carcinogens used in some reprographic machines (see Working Women Education Fund, 1980).

Case Studies

Once again, the case studies underline the contradictory consequences of the new technologies. Kraft (1984) found that computer programmers at all levels were highly satisfied with their jobs, even in highly routinized workplaces. There were no significant differences in satisfaction between men and women in spite of major pay differences.

Machung's (1983) respondents reported that the interpersonal parts of their jobs, not the technical, provided what satisfaction they received. Interpersonal skills, along with organizational ones, are acquired skills and constitute a craft that is assumed to be inherently feminine and therefore an intrinsic part of a secretary's makeup. Unlike the technical part of a secretary's job, they are invisible skills and need not be paid for. Machung stresses the persistent paternalism of the job: "success for the secretary . . . is vicarious and internalized" (Machung, 1983:119).

Bikson and Gutek (1983) surveyed a nonrandom sample of 530 employees who used advanced information technology in 26 private-sector organizations. The technology had been in use for a minimum of six months; none of the employees was a computer professional although some were "data-oriented professionals." Employees were not afraid of the technology (Bikson and Gutek, 1983:14):

> In contrast to widely publicized speculations about managerial and professional resistance, we found that employees at these occupational levels were both willing and able to convert to computerized systems; indeed, their responses to information technology are significantly more positive than those of the support staff . . . . Respondents were significantly more positive about how the computer might affect the quantity and quality of their own work than they were about how it might affect the quality of working life.

Bikson and Gutek cite two major findings: (1) variety in work significantly predicts the use of new computer-based systems and (2) the organization's orientation to change predicts level of systems use and user satisfaction. These are additional reasons not to treat the office like a factory waiting to be automated: "White collar workers appear to adapt more readily to innovative information systems in organizations where such change is viewed as a positive, problem-solving, and achievable goal" (Bikson and Gutek, 1983:17):

> These organizational findings . . . strengthen our belief that problems with implementing computer systems in white collar settings are not technological in nature. Users think technology itself is fine. What affects how much and how well it is used are organizational, environmental, and training matters that organizations should be able to address.

TECHNOLOGICAL CHANGE, WOMEN, AND MINORITIES

The studies reviewed here indicate that technological changes have affected different people in different and complex ways. For example, the first experiments in white-collar homework using telecommunications technologies have been tried almost exclusively with women clericals. Employers have been reluctant to try the new technologies with professionals and managers (see Olson, 1983).

In office work, although average skill levels in a purely arithmetic sense rise as a result of removing the least-skilled clerks and data-entry personnel, channels of occupational mobility between clerical and professional/managerial jobs are being eliminated in the process. Women are most likely to suffer as a result because they are most heavily represented in the low-level clerical/data-entry jobs that are disappearing. Moreover, the effects on women vary by race and class. The lowest-level clerical jobs are those with the highest concentration of women. These are scheduled for elimination, not simply deskilling (Feldberg and Glenn, 1983; see also Hacker, 1979). White women with higher educational levels will probably benefit the most from the upgrading of remaining clerical jobs: they will continue as a skilled if low-paid and dead-end work force, i.e., "jobs but not opportunities" (Baran and Teegarden, 1984).

The mobility opportunities are also mixed in computer software occupations. Programming is considerably more open to women than are other technical and scientific occupations. The occupation is relatively new, yet a pattern of gender segmentation has already emerged. In the standardized software workplace there are virtually no black software workers, and women play the same role as they do in the office: cheap, educated, and responsible workers. Women are disproportionately in low-level technical specializations and in the so-called mediator jobs. When major variables such as education and length of employment are held constant, women are paid on average 15 percent less than their male counterparts in all specializations. The discrepancies are greater in small organizations than in large ones and for management-level workers than for technical workers. In no industry, occupational specialization, or bureaucratic level do women earn as much as men. The gender segmentation in computer software work is noteworthy because it is a relatively new occupation that has always had a significant minority of women and for which there has always been a strong demand. Although a "high-tech" occupation, it has reproduced many of the same male-female segmentation patterns characteristic of both old and new clerical work.

SUMMARY AND EVALUATION

We began this review by asking about the effects of the new technologies on specific issues. What conclusions can we now draw?

Employment Levels

The effects of technological change on employment levels cannot be measured precisely. Although the studies and projections reviewed here are methodologically sophisticated, they are not yet adequate to the complexity of the problem: it is difficult to isolate the effects of "technology" from other major factors.

There is no doubt, however, that new jobs are created by technological innovation and old jobs destroyed. There is, on the other hand, considerable doubt about the long-term consequences for aggregate employment levels. The major study of technology and aggregate employment (Leontief and Duchin, 1984) predicts significant job losses in some occupations and industries, growth in others, and a major, but not catastrophic, decline in the overall demand for labor by the year 2000. The predictions consider only computer-based technological change, however, and not structural changes in the economy, production innovations other than those based on computer technology, or nontechnological factors that might affect production and productivity. Aggregate forecasts built around a single variable by necessity remain problematic and open to ongoing qualification.

The difficulties of making economy-wide forecasts are illustrated in actual trends in sectoral employment. Employment levels in clerical work and metalworking have reflected market conditions as much as computer-based technological changes. In the case of clerical work, work rationalization has accompanied, not caused, market expansion, and aggregate clerical employment has increased (Baran and Teegarden, 1984; Appelbaum, 1984; Feldberg and Glenn, 1983). A different situation holds in auto making. A shrinking market first reduced employment levels, then accelerated investment in robotics technologies. Hunt and Hunt (1983) anticipate that natural attrition will shield currently employed auto workers from technological unemployment, but later job-seekers will confront fewer jobs as the new technologies are implemented.

Even in the case of two agricultural commodities facing similar labor shortages, two distinct paths of technological innovation were followed: a radical transformation of harvesting technology among the processing-tomato producers and an evolutionary development by the lettuce growers (Friedland et al., 1981). Here is a clear-cut situation in which technological innovation was affected by the anticipated supply of labor, not the other way around. Technological choices, in other words, were based on social and political considerations--the availability of a steady supply of labor, the probability of unionization, the relative strengths of the larger and smaller growers--rather than on any inherent technological imperative.

Whether computer-based automation will cause significant job gains or losses then, is still an open question. What is clear is that computers and computer-based equipment will not require a large number of highly skilled, well-paid specialists. The findings of Kraft (1979, 1984) and others that computer programmers and systems analysts constitute a small and shrinking percentage of the total U.S. labor force underline the forecasts of Leontief and Duchin (1984) and Rumberger and Levin (1984) that growth in the absolute employment levels of high-tech specialists will be modest. Whatever the medium- and long-term consequences of the new technologies, relatively few high-technology jobs have been created up to now (Rumberger, 1984; Rumberger and Levin, 1984). It is unlikely that the number of such jobs will equal conventional jobs lost through technological innovation.

In sum, the major uncontroversial findings about employment levels include:

- The major direct effect of technological change is to transform existing work and workplaces, that is, to eliminate or substantially alter traditional occupations, as well as create new ones.
- Technology will have important indirect effects on the U.S. economy. Economists generally believe that innovations will increase productivity and thus the competitive position of U.S. producers. Secure and growing markets will be more important to overall employment levels than the direct displacement or creation of jobs through technological innovation.
- Although jobs that require high levels of education and pay well are created by the new technologies, the occupations that are growing fastest in absolute terms are decidedly low-tech and low- paying. In other words, conventional low-skill,

low-paid jobs are increasing faster than high-paid, high-skill jobs in the economy as a whole.

Skill

Skill remains a definitional quandary, and conclusions about the effects of technology therefore must be even more tentative here than in the area of employment levels. The reviewed studies do not resolve the issue of whether skill is an individual attribute, a characteristic of the job, or a social or collective relationship such as autonomy or control. Although many of the studies of skill are also methodologically sophisticated, they vary so greatly in their definitions and assumptions that comparisons are difficult. The problem is best illustrated in the overall findings of the aggregate and sectoral findings, which show little overall change in skill levels in the short and medium term; and the case studies, which tend to show a loss of skills in specific industries, occupations, or specializations.

If they disagree on the overall impact of technology on skill, the studies have helped sharpen an important question: should we focus on the skill impacts of automation on individual jobs, the affected organization, or on the society as a whole? For example, if the overall skill levels of banks are raised when the least-skilled workers are fired, should we be content to to measure the impact on the relatively fewer bank workers who now do more work or on the labor force as a whole, which exhibits no decrease in the proportion of low-skilled workers? Are we seeing a process in which workers have a greater scope of responsibility but less control, i.e., do the new technologies increase workloads without a corresponding increase in workers' authority, discretion, or autonomy? At the moment, Spenner's (1984) general conclusions seem the most reasonable: we are still looking for a definition. As with employment levels, the skill level of the work force, whether it has gone up or down, reflects more than just technological change.

Ultimately, whatever the approach, skill should be dealt with as a political issue as much as a commodity that is acquired, lost, degraded, or enhanced. Skill may be like a commodity, but its definition is more open to negotiation than to measurement. What defines "high-skill" and "low-skill" jobs is probably as much the outcome of the relative bargaining strength of employers, employees, men, women, majority, and minority workers as it is mastery over a production technology.

It is not sufficient to say, in this respect, that old skills are not actually lost but just made obsolete by market forces. The market operates in a predictable way, but it is set in motion by institutions and people who make choices about the organization and technology of production. Some of those choices involve replacing old jobs with new ones or eliminating some jobs altogether. The old job skills were <u>made</u> obsolete; they did not <u>become</u> obsolete. The task is to figure out whether the lost skills were cast aside as a result of the technological change or deliberately designed out of the production technology for reasons of cost or control. For example, the combination of the internal combustion engine and taylorism produced the cheap car. An unintended consequence was to effectively eliminate most blacksmithing jobs. In contrast, the introduction of robots in auto-assembly plants is intended to reduce the employment of welders and painters in order to both shrink labor costs and enlarge management control.

Work Quality

On the whole, studies of work environment and new technology are fewer and of lesser quality than those on employment levels and skill. Why work environment in technologically advanced workplaces has received (relatively) less attention is itself an interesting issue, although obviously beyond the scope of the present review.

A recent study of homework (Olson, 1983) raises an interesting question: because computer-based work can be decentralized, does this also mean that control is also decentralized or even weakened? Long before computers, the design, distribution, and higher-level management tasks had been separated from production. Production itself was often fragmented on a global level for recombination at some final assembly point, e.g., the General Motors model developed by Alfred Sloan. Sloan's decentralized structure was implemented precisely to enhance control. What kinds of authority and control relations will characterize the ultimate decentralized workplace? Will it, too, exhibit a pattern of gender segmentation found in much of the conventional labor market?

Technology, Minorities, and Women

Of all the studies reviewed here, the most consistent findings are in the studies of the impact of technological change on women and minorities. The studies of the insurance industry and of clerical workers in general are carefully done and comprehensive. They find, with minor exceptions, that the consequences of technological change in the clerical work force have been mixed, although not ambiguous. The case studies of Appelbaum, Baran and Teegarden, Murphree, Machung, and Feldberg and Glenn agree that office automation has eliminated (or redistributed) many of the most menial tasks in clerical work. On the other hand, responsibility has often increased without corresponding increases in autonomy or control, and opportunities for mobility have been truncated, i.e., an increase in the breadth but not depth of clerical work for those women whose jobs have not been eliminated by computerization.

The case studies make clear that redesigning jobs to make use of cheap female labor has been facilitated by automated processing, but not driven by it (Baran and Teegarden, 1984:10):

> . . . we suggest that there is a mutually determining interaction between the reorganization of the office labor process and the changing role of female labor in the economy as a

> whole. . . . In other words, women are not just differentially affected by this reorganization; the availability of a growing pool of cheap, educated female labor is itself an important variable in the process.

Even in high-tech occupations such as computer software, the situation is mixed. In terms of the percentage of women (but not blacks), computer programming is the most open of all technical and engineering occupations. Yet, female software workers on average earn only about 75 percent of their male colleagues and they are concentrated in specializations with a heavy "support" component. In this highest of high-technology occupations, conventional sex roles have been reproduced, not eliminated.

Among women, race and class will play important roles. The clerical jobs most likely to be lost, particularly data entry and typing, have high percentages of minority women. Better-educated white women are likely to benefit from office automation, at least in the short run. The process is exacerbated by the choice of some firms to move to suburban or rural settings, where minority populations are low (Baran and Teegarden, 1984). Although white women above the lowest skill levels are benefitting now, their mobility opportunities, too, are being cut off by the increasingly rigid segmentation being built into the new jobs.

Politics and Technology

Historically, changes in how we make things have generated fears about what those changes will do to jobs and quality of work. Economists, in particular, have sought to calm those fears by making the argument that anything that increases productivity makes a firm or industry more competitive. When that happens, more goods and services are sold and employment rises.

This may have been true (within the limits of economic cycles), but will it hold true in the future? The introduction of computer-based production technologies is in some respects clearly an extension of a much older process of industrialization. But are computer-based technologies merely incremental changes in how our work is done?

The evidence suggests that computer-based technologies differ from earlier forms in several significant ways:

- They can be applied to professional and managerial occupations as well as to occupations that rely primarily on manual or clerical skills. Modern technologies can also be applied to occupations outside traditional production workplaces, e.g., in health care, education, service, and retail industries.
- Middle- and upper-level management jobs are being transformed, as well as created and eliminated.
- Some new high-tech jobs, including the prototypical computer occupations, are probably as vulnerable to technological/organizational rationalization as older and more conventional jobs.

Together, these differences mean profound transformations in all work. Until now, most technological innovations have been introduced in workplaces to standardize and routinize first physical and then clerical tasks. Although the process of standardization required the separation of management and design from production, standardization was usually limited to the physical or clerical component of the production process: management and design seemed to present a "natural barrier" to standardization and mechanization. That "natural barrier" has collapsed in the face of computer-based technologies. In this respect, Hunt and Hunt (1983) are too sanguine about the evolutionary nature of current technology: it is more accurate to say that computerization is the revolutionary, if logical, next step in the taylorization of office work. The chief executive of Olivetti, the European office machinery firm, described the process bluntly (De Benedetti, 1979):

> Standardization is the necessary prerequisite to the subsequent mechanization and automation of the productive process . . . . Data processing is . . . a continuation of a story which began with the industrial revolution . . . it is basically a technology of coordination and control over a labor force, the white collar workers, which taylorian organization does not cover . . . . In this sense, edp [electronic data processing] is in fact an organizational technology and, like the organization of labor, has a dual function as a productive force and a control tool for capital.

We have witnessed, according to De Benedetti,

> . . . a shift from hierarchical structure towards a polarization, with the elimination of intermediate groups and . . . a centralization of information and decisions prejudicial to middle-managers.

Modern technologies are different because they can automate a much broader range of work and workplaces. However, modern technologies also share certain fundamental characteristics with their predecessors. They are applied primarily as labor-saving devices. They require the standardization of work as the precondition, not the consequence, of their application. In practice, they tend to centralize, not decentralize, managerial control.

How science is applied to a given production process and what production process is to be the subject of technological innovation are not themselves technical questions: they are choices based on political, economic, and social criteria, not natural laws. The flexibility of technology underlines the warning made several decades ago by an early pioneer of computer-based automation: any given technology may have embedded in it a set of values that are disguised as scientific truths and inevitabilities (Wiener, 1954).

What will those values be? It is important to note that all of the technological innovations discussed in this review were initiated by management. All were introduced either to secure a steady supply of labor or to replace labor completely or in part. None was designed to increase labor use or to transfer control and discretion from managers to workers. If we want high productivity at lower labor costs, do we also want to build into our technologies a way of providing employment for displaced workers? Do we want to provide opportunities for women and others who have been traditionally excluded from good jobs with reasonable futures? These choices are as technologically possible as those we have made up to now.

REFERENCES

Adler, Paul

1983 Rethinking the Skill Requirements of New Technologies. Boston: Graduate School of Business Administration, Harvard University.

1984 New Technologies, New Skills. Boston: Graduate School of Business Administration, Harvard University.

Albin, Peter S.

1984 Job design within changing patterns of technical development. Pp. 125-151 in Eileen L. Collins and Lucretia D. Tanner, eds. American Jobs in the Changing Industrial Base. Cambridge, Mass.: Ballinger.

Albin, Peter, S., and Charles Bahn

forthcoming Job complexity and worker perceptions of job content. Journal of Occupational Behavior.

Appelbaum, Eileen R.

1984 The Impact of Technology on Skill: Requirements and Occupational Structure in the Insurance Industry, 1960-1990. Philadelphia: Department of Economics, Temple University.

Baran, Barbara, and Teegarden, Suzanne

1984 Women's Labor in the Office of the Future: Changes in the Occupational Structure of the Insurance Industry. Berkeley: Department of City and Regional Planning, University of California.

Bikson, Tora K., and Gutek, Barbara A.

1983 Advanced Office Systems: An Empirical Look at Utilization and Satisfaction. Santa Monica, Calif.: The Rand Corporation.

Blauner, Robert

1964 Alienation and Freedom: The Factory Worker and His Industry. Chicago: University of Chicago Press.

Braverman, Harry

1974 Labor and Monopoly Capital: The Degradation of Work in the Twentieth Century. New York: Monthly Review Press.

Bright, James

1958 Automation and Management. Boston: Graduate School of Business Administration, Harvard University.

De Benedetti, Franco
1979 The Impact of Electronic Technology on the Office. Paper presented to the Conference on Tomorrow in World Electronics, London, England.

Dubnoff, Steven
1978 Inter-occupational Shifts and Changes in the Quality of Work in the American Economy, 1900-1970. Paper presented to the meetings of the Society for the Study of Social Problems, San Francisco, Calif.

Dubnoff, Steven, and Kraft, Philip
1984 Gender Stratification in Computer Programming. Paper presented to the meetings of the Eastern Sociological Society, Boston, Mass.

Feldberg, Roslyn, and Glenn, Evelyn N.
1983 Technology and work degradation: effects of office automation on women clerical workers. Pp. 59-78 in Joan Rothschild, ed., Machina Ex Dea: Feminist Perspectives on Technology. New York: Pergamon.

Friedland, William, Barton, Amy E., and Thomas, Robert J.
1981 Manufacturing Green Gold: Capital, Labor, and Technology in the Lettuce Industry. New York: Cambridge University Press.

Greenbaum, Joan
1979 In the Name of Efficiency: Management Theory and Shopfloor Practice in Data Processing Work. Philadelphia: Temple University Press.

Hacker, Sally
1979 Sex stratification, technology and organizational change: a longitudinal case study of AT&T. Social problems 26(5):539-557.

Hunt, H. Allan, and Hunt, Timothy L.
1983 Human Resource Implications of Robotics. Kalamazoo, Mich.: The W. E. Upjohn Institute for Employment Research.
1984 A Critique of "The Impacts of Automation on Employment, 1963-2000" by Wassily Leontief and Faye Duchin. Kalamazoo, Mich.: The W. E. Upjohn Institute for Employment Research.

Kraft, Philip
1979 The industrialization of computer programming: from programming to "software production." Pp. 1-17 in Andrew Zimbalist, ed., Case Studies in the Labor Process. New York: Monthly Review Press.
1984 The Automation of Work. Paper presented to the the Bell Commmunications Conference on Technology and White Collar Work, New Brunswick, N.J.

Kraft, Philip, and Dubnoff, Steven
1984 The Division of Labor, Fragmentation, and Hierarchy in Computer Programming. Paper presented to the meetings of the Eastern Sociological Society, Boston, Mass.

Kusterer, Ken
1979 Know-How on the Job: The Important Working Knowledge of "Unskilled" Workers. Boulder, Colo.: Westview Press.

Leontief, Wassily, and Duchin, Faye
1984 The Impacts of Automation on Employment, 1963-2000. Final Report to the National Science Foundation. New York: Institute for Economic Analysis, New York University.

Levy, Robert, and Jondrow, James
1984 The Adjustment of Employment to Technical Change in the Steel and Auto Industries. The Public Research Institute. Alexandria, Va.: The Center for Naval Analyses.

Levy, Robert, Bowes, Marianne, and Jondrow, James
1983 The Adjustment of Employment to Technical Change in Steel, Autos, Aluminum, Coal and Iron Ore. The Public Research Institute. Alexandria, Va.: The Center for Naval Analyses.

Machung, Anne
1983 From Psyche to Technic: The Politics of Office Work. Unpublished Ph.D. dissertation. Department of Political Science, University of Wisconsin.

Murphree, Mary
1981 Rationalization and Satisfaction in Clerical Work: A Case Study of Wall Street Secretaries. Unpublished Ph.D. dissertation. Department of Sociology, Columbia University.
1984 Brave new office: the changing world of the legal secretary. In Karen Sacks and Dorothy Remy, eds., My Troubles Are Going to Have Troubles with Me: Everday Trials and Triumphs of Women Workers. New Brunswick, N.J.: Rutgers University Press.

Noble, David
1979 Social choice in machine design: the case of automatically controlled machine tools. Pp. 19-50 in Andrew Zimbalist, ed., Case Studies in the Labor Process. New York: Monthly Review Press.

Office of Technology Assessment
1984 Computerized Manufacturing Automation: Employment, Education, and the Workplace. Available from the U.S. Government Printing Office. Washington, D.C.: Office of Technology Assessment, U.S. Congress.

Olson, Margrethe H.
1983 Overview of Work-at-Home Trends in the United States. Center for Research on Information Systems. New York: College of Business and Public Administration, New York University.

Rumberger, Russell W.
1984 High Technology and Job Loss. Project Report No. 84.AR. Institute for Research on Educational Finance and Governance. Stanford, Calif.: School of Education, Stanford University.

Rumberger, Russell W., and Levin, Harry M.
1984 Forecasting the Impact of New Technologies on the Future Job Market. Project Report No. 84-A4. Institute for Research on Educational Finance and Governance. Stanford, Calif.: School of Education, Stanford University.

Spenner, Kenneth I.
1984 The Upgrading and Downgrading of Occupations: Issues, Evidence, and Implications for Education. Durham, N.C.: Department of Sociology, Duke University.

Wiener, Norbert
1954 The Human Use of Human Beings. New York: Doubleday.

Working Women Education Fund
1980 Race Against Time: Automation of the Office. Cleveland, Ohio: Working Women Education Fund.