Some Computer-Based Developments in Sociology

David R. Heise and Roberta G. Simmons

Summary. Sociological data sets are now being computer analyzed by means of a variety of sophisticated procedures, to produce results that reflect the intricacy of social life. Computers also are being used to conduct simulations of social processes based on mathematical models and to collect the data for analysis. Portable computers allow computing power to be used in field studies, and the relatively low cost of computers is expanding the range of sociologists who use them. While opening up new research opportunities, computers also bring certain problems for social researchers and teachers.

Computers are revolutionizing treatments of all kinds of sociological data. The revolution is just beginning in the case of qualitative materials. It is far advanced in the case of research involving quantitative materials (*1*, p. 438):

> In 1946, 54% of the substantive articles published in the *American Sociological Review* lacked any type of mathematical analysis at all. In the *American Journal of Sociology*, 46% of the substantive articles were completely without mathematical analysis. By 1976 only 12% of *ASR* articles and 14% of *AJS* articles lacked mathematical analysis. Since some journal articles are legitimately theoretical, or in some other way inappropriate for the use of mathematical analysis, the contemporary figures must represent something close to saturation. Clearly, quantitative methods have been firmly institutionalized during the mainframe computer era.

In this article we survey some of the ways in which computers are being used in sociology and how they continue to change the discipline. We write as observers in the field, reporting what we see of a revolution in progress. We have no pretensions as historians of science or as sociologists of science. An exhaustive review is precluded in any case by the brief time frame allowed for the preparation of this article. Examples of recent research have been selected to illustrate central points; no attempt is made to judge which substantive work is most important to sociology.

The Sociological Enterprise

Sociologists endeavor to describe patterns in the social world, taking account of noise and errors of measurement, and they try to analyze the causal processes that produce the phenomena in question. Prediction of future social processes is an ultimate but less emphasized goal. The discipline deals primarily with archival data, although important branches of sociology use direct observation and experimentation. Archives of quantitative data are assembled from sample surveys, censuses, bureaucratic recordings, and the like; qualitative archives include field notes from long-term observational studies, transcribed interactions including interviews, and historical documents of all kinds.

The sample survey has been the central method of data collection in sociology. That is so because the range of life conditions associated with social organization cannot be assigned randomly in order to experiment with effects. For political and ethical reasons, sociologists must study the natural distribution of social factors. Each respondent is subjected to a particular pattern of social influences, and the aggregate of respondents can be studied to assess the impacts of those factors. Surveys can be, and are, supplemented by traditional experiments; but experiments in sociology are not routinely the method of choice. Too often, the more a variable can be controlled, the less likely it is that that variable will be related to important matters of power and privilege.

Sociological investigators frequently use long interview schedules, and these are a means of dealing with another problem in sociology: the fact that social position controls not one or two but a multitude of conditions of life. Socioeconomic status, for example, relates to the kind of work one does, the physical environment and resources for that work, one's level of income and prestige, the level of economic power, the type of leisure activities, the material conditions of home life, the material environment one experienced as a child, and the kind of education one received. We typically are not sure which of these factors are the crucial ones influencing a particular outcome. It is necessary to consider all the factors and numerous questions must be asked to gather all the data.

The data that sociologists use often come from fallible sources—from the subjects themselves with their conscious and unconscious defenses, from bureaucratic records, or from reporters with unknown biases and accuracies. Moreover, sociologists sometimes must approach respondents in multiple subcultures, and identical questions may not have the same meaning in all. Analyses must make allowance for various sources of error.

Because it is a discipline heavily based on sample surveys of thousands of cases and hundreds of measures on each case, sociology has been dramatically affected by the computer. One of the major impacts of the computer, in fact, has been on the sizes of samples. Ten years ago a sample size of 1000 or 2000 was considered large. Today, because of the computer, major data sets have been collected with ten times as many cases (*2*, *3*).

In addition, the U.S. Census Bureau has made many very large Public Use Data Files available for analysis, and similar files from other nations have also become available. Fifteen years ago demographers analyzed primarily public records and dealt with aggregate-level properties or with the few individual-level variables associated in the published sources. The first computerized Public Use File for the U.S. Census, based on a 0.1 percent sample of the 1960 census, was made available in 1962; in the 1970's and 1980's, more Public Use Files gradually became available. Today, with the availability of Public Use Data Files from various historical periods and many nations, demographers can analyze relations among many variables at the individual or household level and thereby secure a better understanding of causal processes over time and over age,

D. R. Heise is in the Department of Sociology, Indiana University, Bloomington 47405. R. G. Simmons is in the Department of Sociology, University of Minnesota, Minneapolis 55455.

whether they are interested in explaining fertility behavior, household composition, migration patterns, social mobility, racial and ethnic differentiation, or a variety of other social patterns (*4, 5*).

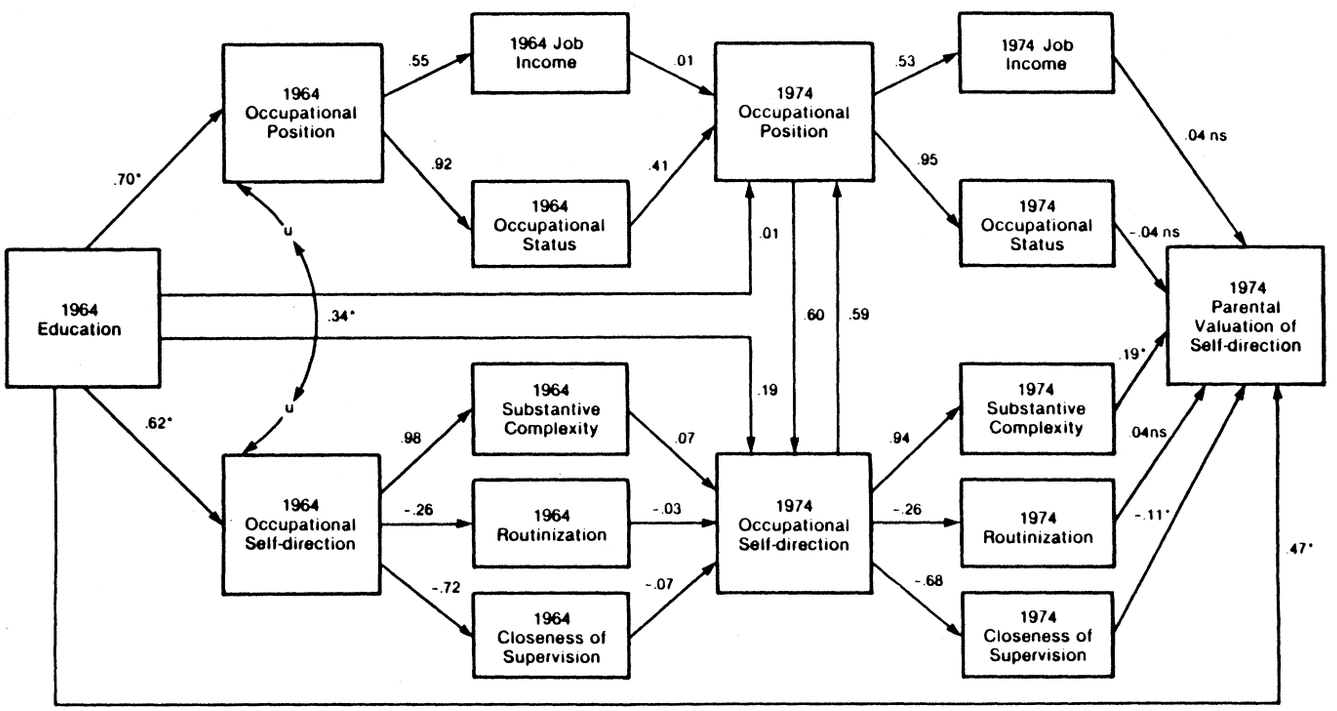
Large data sets have several advantages. More variables can be studied simultaneously and more intricate causal processes investigated. Furthermore, some of the most important sociological phenomena, such as catastrophes of all kinds—riots, business failures, suicides—are rare events. Very large archives must be assembled to obtain even moderate numbers of such cases. For example, the National Crime Panel surveys have interviewed approximately 60,000 households every 6 months for up to $3\frac{1}{2}$ years in order to locate the relatively rare cases of certain types of victimization, such as rape (*6*). In one recent sample of 8003 youths (grades 5 through 9), investigators found that 11.4 percent of the youngsters admitted that they worried that they might kill themselves. Thus, this study provided a subsample of over 900 potentially suicidal children for intensive quantitative investigation (*7*).

Not only has the availability of the computer allowed much larger data sets, but it has also permitted the simultaneous examination of the complex interrelations among many more variables. Twenty years ago, studies of the simultaneous relations of three or four variables in survey data was the common practice. Today, with the aid of computer technology, intricate causal models such as that depicted in Fig. 1 are common. The figure, from a larger study by Kohn and Schooler (*8*), depicts an analysis of the causal pathways through which education influences parental child-rearing values over time. The larger study, which has been termed "path-breaking work" (*9*), investigates the mutual causal interrelations between job characteristics and social-psychological variables. The investigators question whether initial correlations simply are due to the selection of certain types of jobs by individuals with certain personality and intellectual characteristics, or whether key job characteristics (the substantive complexity, closeness of supervision, and routinization of the job) also affect changes in personality, mental health, intellectual style, and child-rearing values.

Complex Statistical Techniques

Social research conducted via sample surveys, then, makes it necessary for the investigator to deal simultaneously with dozens of imperfect measurements, in order to define complex causal models, often using thousands of empirical observations. Coping with the analytic problem has occupied a significant portion of sociologists' time in the last 40 years. Sociologists have been great borrowers—from statistics, biometrics, psychometrics, econometrics—and we have also developed techniques on our own. A major result is a family of analytic techniques that might generally be called structural equation modeling. To use these techniques, one hypothesizes about the dependencies that are likely to exist among variables, converts conclusions to equation form, and then uses data to solve for parameters of the system. Because of the power of mathematics, conclusions can then be reached about variables that have not been measured directly and about relations where direct reasoning could provide no answers. Structural equation modeling combines available knowledge, empirical data, and mathematical analysis. Better knowledge, better data, better mathematical analysis may yield new conclusions, but that process of revision is no different than the progression of knowledge through improved experiments.

Computing power has fostered a new generation of statistical techniques for implementing structural equation methods. A program entitled LISREL (Linear Structural Relationships) by Jöreskog



χ^2 (for causal model) = 424.17
d.f. = 213
ratio = 1.99
* = Statistically significant, p≤.05;
ns = Nonsignificant; other parameters are fixed.

Fig. 1. The effects of education, occupational position, and occupational self-direction on parental valuation of self-direction (paths from social characteristics to endogenous variables and correlations among residuals are not shown). [From (*33*)]

and Sörbom (*10*) provides one example. LISREL provides maximum likelihood estimates of parameters for sets of simultaneous equations where some parameters relate to measurement constructs and other parameters define causal relations among latent variables. The program devotes major emphasis to dealing with certain types of measurement error in the causal analysis. In addition, the procedure can deal with mutual causality among variables in an adequately designed data set. Results produced by the program include parameter estimates, statistical tests of significance for the parameter estimates, and a global test of fit for the model as a whole.

Some of the current statistical techniques, such as the maximum likelihood estimates involved in LISREL, compute their solutions iteratively, working in small steps toward an adequate solution that cannot be defined analytically. The iterative approach is practical only when an abundance of computing power is available, and in this sense computers are the foundation for application of these techniques.

There are many other complex statistical calculations that allow simultaneous investigation of relations among variables that would be very difficult without the rapidity of present-day computers: for example, multivariate analysis of variance, repeated measures analysis of variance, canonical correlations, log-linear analyses of tabular data, logistic and probit regression, metric and nonmetric multidimensional scaling, hazard models, and event-history analysis. Because computers are widely available, these techniques can now be used to analyze data collected from sample surveys and from experiments. Thus, computers have allowed some old but powerful procedures of data analysis to be put to practical use.

More impressive, modern computers have led to the development of many new techniques, and it is no longer necessary to be intimidated by computation. New generations of methodologists have emerged, with great competence in mathematics and computer technology, who continue to innovate in statistics relevant to sociology. Just this year (February 1985) the 16-year-old annual volume *Sociological Methodology* sponsored by the American Sociological Association was changed into a semiannual journal to reflect this increasing emphasis.

Substantive examples. In the 1984 issues of the *American Sociological Review* (the major official sociology journal), the majority of the studies used a computer analysis based on one or more of the complex statistical techniques. Among the wide range of such studies for which the techniques were applicable were the following: (i) a study of the mutual effects of unemployment and criminal involvement upon one another, among men in their early 20's, over a 4-year period (*11*); (ii) an investigation of the process by which the father's social class position and the son's education in five capitalistic societies affect the reproduction of class position over the generations, in terms of ownership of the means of production and of purchase and control over labor power (*12*); (iii) a study of the mutual causal interrelations between level of well-being and exchanges of help between adult children and their elderly parents (*13*); and (iv) a study of the pattern of intragenerational occupational mobility among black men from 1962 to 1973, with a focus on the effects of race versus the effects of social class origins (*14*). In these cases, it is not the questions that are new but the ability to provide better answers.

Studies of the structure of relations among individuals, organizations, or collectivities involve "network analysis," a kind of research that would be crippled without computers. For example, David Knoke and Edward Laumann (from Indiana University and the University of Chicago, respectively) have focused on interrelations among 198 energy organizations and 135 health organizations—the organizations that appear to be the most influential and consequential participants in national policy-making in the two domains. They have collected information about the regular consultation patterns among these organizations concerning national policy. The resultant matrices contain hundreds of nodes; the manipulation of such matrices to identify comprehensible network patterns and to test these patterns statistically would be impossible without the computer.

Nonstatistical Analyses

Qualitative data. The greatest impact of the computer in sociology has been the analysis of quantitatively measured data—data based on multiple-choice questions in sample surveys or other kinds of counting. As noted above, the size of data sets has increased and much more complex causal models and sophisticated statistical techniques are now being used. However, many sociologists collect more in-depth qualitative data from open-ended interviews, from observations of social systems, and from written documents. Computers are becoming increasingly important for processing such data, allowing more systematic analysis and retrieval than the prior hand indexing, cutting, pasting, and filing of thousands of pages. A recent special issue of *Qualitative Sociology* billed itself as a first "guidebook by some of the early explorers of what computers can do for qualitative sociology" (*15*, p. 12). Many of the approaches currently being developed (*16, 17, 18*) extend the computerized content-analysis tradition launched two decades ago with the General Inquirer Program by Stone *et al.* (*19*).

Most important in qualitative studies, the computer can act as a clerk with a perfect memory and with the ability to retrieve all examples of whatever indexed, conceptual categories or words are of interest (*20*). Massive amounts of time and tedium are saved whether one is Eder (*21*) attempting to analyze volumes of field notes concerning interactions in junior high school; or Grimshaw (*22*), who studies naturally occurring talk; or Cole and Zuckerman (*16*), who use in-depth interviews with men and women scientists to study scientific careers. In all cases, the search of qualitative data for patterns and meaning becomes easier and accuracy is increased when computers are used.

Not only is time saved, but rigor at all stages of analysis can be increased. In 1968, Robert Merton pleaded for codification of qualitative analysis, with something of the clarity characterizing quantitative methods (*15*). The increasing use of the computer in qualitative analysis may finally provide a record of a process previously regarded as private and mysterious (*15*) . The link between data and theory should become clearer and more verifiable as both the original qualitative archives and the outputs of conceptual analysis become computerized and available. Furthermore, since codification of some type will be required ahead of time and since there will be revisions over time and across investigators, the linkages among conceptual schemes should become more explicit.

The computer thus provides the potentiality for increased collaborative work. There would be an obvious advantage for several qualitative investigators to study large numbers of situations or social systems simultaneously in order to discover similarities and distinctions of interest to theory. There have been few such studies up to now. However, the

computerization of qualitative data would allow files to be shared, and various conceptual schemes to be coordinated, without geographical distance precluding collaboration. Later use of the same data by other investigators and later replications with other data sets should also be enhanced.

At present, a polarization of qualitative and quantitative research characterizes sociology. If these computer developments earn a widespread acceptance, it will be interesting to see whether polarization is reduced. Also of interest will be the effects of new work in artificial intelligence in the development of computer programs that understand sentences and longer units of text (*23*).

Simulations. Data analysis techniques use the computer to condense myriad empirical details into a summary pattern. Simulations use the computer as a tool for finding the detailed implications of a complex theory or model. A computer is required when the logical operations are too burdensome to conduct mentally because of the mathematical complexity of the model or because deductions have to be obtained with continual reference to a large database that provides the context for analysis.

For example, one social psychological theory proposes that people create events in order to confirm culturally given meanings (*24*). Although the basic principle is simple, the mathematical model for the theory is large and complex, requiring a simulation program (*25*) in order to understand the implications of the theory for social interaction. Each round of analysis uses a large set of empirically based nonlinear equations, conducts hundreds of thousands of arithmetic operations, and searches dictionaries containing verbal and quantitative information on several thousand entries. Computer simulation with this program shows that specifying role-identities for interactants (such as doctor and patient, or father and daughter) is sufficient for deriving sets of contingent expected behaviors for each person plus the emotions that should accompany the behaviors.

As another example, Peter Marsden at the University of North Carolina is modeling social exchange processes, focusing on brokerage—actors who mediate exchanges between others having no direct relations. The goal is to examine the redistribution of power and resources through a large network, as brokers extract "payments" for their services. The calculations must be applied iteratively to discover net effects in the whole system, and massive amounts of computing are required when simulations are conducted for real-life communities of more than a hundred actors—upwards of 30 minutes of mainframe central processing unit time.

In still another example of fundamentally new work, Caldwell (*26*) conducts microanalytic simulations of economically determined social processes. He starts with a sample of several thousand individuals who are hypothetically moved forward in time several years, in order to explore effects of various negative income tax policies on marriage, work, earnings, and savings. The model uses equations from prior research that describe relations among the relevant variables. In this case a computer is required for the simulation because extensive computations are being conducted on a large sample of cases.

Data Collection

Although the most obvious impact of the computer in sociology has involved data analysis, data collection has been revolutionized as well. Computers aid in constructing good random sampling designs for sample surveys so that one can generalize with confidence from one's sample to the larger population. For example, with random digit telephone dialing the computer produces a set of telephone numbers randomly drawn; unlisted and nonindividual phone numbers (for instance, boarding-house central phones) can be included in the list.

The Computer-Assisted Telephone Interviewing (CATI) system is now being used at 30 to 40 survey research sites around the United States not only to draw samples but also to aid the interviewing process as well (*27*). A computer displays the next question to ask on the basis of prior answers, and thus fewer branching errors are made than when the interviewer has to make the decision. The interviewer keys data immediately into the computer. This process dramatically reduces research expenses by eliminating pools of coders who customarily have transformed answers into numbers on code sheets which then have had to be key-punched for storage on tape or disk. With fewer steps, there is less chance for clerical errors; furthermore, the CATI package immediately cleans some of the data of errors, pointing out unallowable inconsistencies.

Techniques are being developed so that subjects can interact directly with the computer, eliminating an interviewer entirely along with biases created when an interviewer offers subtle social cues for answering. One example is a program developed by Heise (*28*) to elicit subjects' everyday knowledge. Another example is a computerized panel study in the Institute for Research in Social Science at the University of North Carolina. In this project, created by psychologist Bibb Latané and directed by sociologist Beverly Wiggins, 100 respondents are paid to come in for 90 minutes each week over a period of 20 weeks. In each session, participants confront a variety of tasks on their computer terminals—tasks developed by researchers from various social science departments. Participants respond directly into the computer via their keyboards. Responses from one participant can be fed to another, permitting experiments for studying decision-making, communication, and role-playing. In addition, tests and questionnaires are readily administered with options of closed or open-ended items, graphic stimuli, timed response, and randomized or complex conditional sequencing of questions. Computer terminals are made available to the participants from 9 a.m. to 9 p.m., with the computer totally in charge of greeting participants, administrating tasks, and archiving the data for later use.

The impact of the computer revolution on data gathering is just beginning to reach sociologists relying on verbal and image data. Recent development of laser-disk computer memory systems (*29*) will lead to the availability of massive archives, for example, from *The New York Times*. Computer manipulation of these archives will permit new developments in historical studies, content analysis of political statements, dynamic studies of events such as riots or terrorist attacks, and so on. Films and documentaries on laser disks already provide far more computer-accessible image data than sociologists are capable of analyzing until new methodologies are developed.

Microcomputers

Although big, fast mainframe computers are required for certain analyses and operations we have described—those involving huge data sets or lengthy iterative analyses—many of the analyses can be done on microcomputers, which now offer the capabilities of mainframes in use only a few years ago. Aside from their essential similarities with mainframes, however, microcomputers make

a unique contribution to the computer revolution in sociology.

The portability of microcomputers can be used in the service of direct data collection in the field. For example, one program collects attitude data in a field setting (*30*). The computer, turned over to respondents with minimal information, instructs them and provides practice runs. The program randomizes order of stimuli and orientation of multiple-choice items from a scale, and it checks for over-simplified patterns of response, getting a replication of ratings when it appears that the respondent has not answered seriously. Data are recorded electronically as they are received.

With microcomputers it is possible to reach some respondents who otherwise would be inaccessible for research. For example, a pilot study of conceptions about life forces used Heise's program for eliciting logical hierarchies (*28*), and a microcomputer was taken directly to the offices of biology professors and to those of the creationists who were the subjects in the study. Since neither group of respondents would have offered cooperation if they had to travel to an office to sit at a mainframe terminal, a portable computer was essential.

The more remote the field station and the farther from mainframe computer support, the greater the benefits obtained from portable computers, as anthropologists have been quick to recognize (*31*). Case has described how he prepared a portable computer for operation in an undeveloped setting so that capabilities for database manipulation, statistical analysis, and report writing were available to him without leaving the field where he was studying Mayan civilization (*32*). In the future we may see teams of observers at different locations in the field relaying field notes via computer back to a central source, where they can be integrated and new suggestions for observation developed.

The relatively low cost of microcomputers allows them to be acquired as personal property by individual scientists. Once the initial purchase price is managed, computing time is free, no longer dependent on the maintenance of grants or affiliation with a major university. Noninstitutional ownership of computing power is especially significant for sociology and related fields, the sciences hit hardest by reductions in federal research funding. In fact, microcomputers have made large-scale quantitative research more egalitarian, and new advances in laser-disk data storage may continue the trend. Moreover, microcomputers are less intimidating than mainframes with their surrounding technical bureaucracy. Their low cost and accessibility are fostering movement toward computer use by social scientists who have not previously relied on computers, particularly those who work with qualitative data.

Problems in the Computer Era

Standardization. Lack of standardization in the computer industry presents problems for those who are dependent on the technology. For example, a variety of central processing units are in use with different capacities and different functional capabilities. High-level computer languages moderate problems of transporting programs from one unit to another but do not eliminate problems, and often it is not worth the effort to move software from larger to smaller central processing units. The situation is worse with regard to computer peripherals. For example, magnetic storage media currently encompass at least four different sizes of floppy disks and an even larger number of incompatible tape drives. Operating systems also present a disordered arena. For example, more than a half-dozen operating systems exist for microcomputers and practically none of these are compatible with operating systems for minicomputers and large mainframes. For the most part, the various systems do not communicate with one another and each provides a different language for communications between users and computers. The net result of these standardization problems is that a researcher working with one system frequently cannot expect to share programs or data with investigators using other systems. It is possible that these problems are transitory and will be mitigated in the near future.

Social researchers also have problems with overstandardization and with an absence of any commercial media for some kinds of materials. The latest statistical programs must be distributed from one research center to another: it takes half a decade or more to get them into standard packages of statistical programs. Simulation programs that have research and pedagogical utility must be distributed privately: no other medium of distribution is available. Large data archives often must be visited, rather than obtained, because the data along with support programs and documentation constitute a bundle that is too costly to distribute. These factors mean that there is a lag between what sociologists are capable of doing at any given time and what the majority of them actually do.

Training. Mainframe computers opened the door to powerful statistical analysis of large data sets, and during the 1970's major sociology departments incorporated this fact into their graduate curricula. Training in structural equation modeling, sophisticated tabular analysis, and use of other statistical procedures now is largely routine, a requisite for reading journals. However, the latest wave of the computer revolution is raising new confusions about graduate education.

Powerful statistical packages that appeared in the 1960's and 1970's allowed deemphasis of numerical analysis procedures that were important when computations were made on desk calculators; the time was used instead to focus on the logic, theory, and metatheory involved in social analyses. Now computer power is spawning statistical procedures that can hardly be understood or properly applied without substantial mathematical background. Since students can invest only so much time in methodology as opposed to substantive courses, do we once again deemphasize substantive training in order to provide mathematical training? Or do we set up multiple tracks of training, accentuating the distinction between technical specialists and substantive researchers?

Financing of computing facilities. Some universities offer essentially free access to mainframe computers; others require grant applications and deny requests for large blocks of time; still others provide free computing for educational purposes but demand outside funding for most research projects. However, universities typically end up with restrictive computer administration. This inexorable result arises from the following "law" of time-shared computer systems: usage expands to capacity—new equipment ordinarily is underused so it draws new users and encourages development of more demanding programs, until underusage no longer exists. Thus researchers have adequate access to mainframe systems only while their university continuously expands the capacity of its computing equipment, a condition rarely met. A popular solution is to reserve large mainframes for just the jobs that require extra speed and capacity, distributing other computing to departmental minicomputers. Of course, departmental minicomputers are time-shared, and they eventually succumb to the law of overusage. This in turn invokes another step in distributed computing to personally owned microcom-

puters. Many of the problems of computer access are then solved, but the final step of the solution—acquisition of microcomputers—surreptitiously shifts the burden of supporting computations from institutions to the individual researchers who buy their own equipment.

Conclusions

The demand for data processing power in sociology arises from the nature of the subject matter. Sociologists rarely are able to manipulate one variable of interest while holding all other variables constant. Instead, they search for variations in human affairs that occur naturally, and the effects of one variable must be studied in the context of other variables operating simultaneously. Some important variations occur in only a small proportion of a total population, and many cases must be considered before the ones wanted are found. Moreover, underlying order in social relations often is hidden beneath local patterns and idiosyncrasies so that diverse communities must be studied with a battery of measures before any generalizations can be made. For these reasons sociologists typically collect large data sets at great expense, analyze the data intensively using computers, and keep the data sets in electronic form for use by other investigators.

Sociologists now are routinely using a variety of quantitative methods implemented on computers to build models of social phenomena. In intricacy, methodological sophistication, and effectiveness, these models are stunning advances over what was possible just a few decades ago. The models offer new grounds for winnowing and constructing social theory, as well as for engineering social policy. Success in applying computers to one topic after another has spawned development of new techniques of analysis, and improved technologies extend the substantive range of computer applications. The cycle is far from finished, only now moving into qualitative areas of sociology that have resisted formal analysis longest because of the complexity of the phenomena.

The computer revolution in sociology, like most revolutions, is tumultuous. Advances in methods of analysis raise scientific problems, and meanwhile technology moves on relentlessly, creating new orders of problems while the old problems remain unsolved or are made irrelevant. Technological change undermines cumulation of data and the usefulness of individuals' knowledge, in sociology as everywhere. University departments struggle endlessly to keep their curricula and equipment up-to-date in order to train a new generation of researchers. Sociologists who gain the desire and knowledge to move forward with new technology find that they do not have the resources to proceed. The impact of computers in sociology is perhaps best summarized in the Chinese curse: "May you live in interesting times."

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