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Statisticians Can Matter

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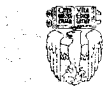

HARRY V. **ROBERTS** began a long-term academic relationship with the University of Chicago when he earned the A.B. degree there in 1943. He went on to obtain an M.B.A. degree with honors, in 1947, and the Ph.D. in 1955 from the same institution. His teaching career with the University started when he was appointed as an instructor in statistics at the School of Business in 1949. Subsequently, he became assistant professor (1951-55), then associate professor (1955-59). Presently, he is professor of statistics at the Graduate School of Business of the University of Chicago.

Prof. Roberts's scholarly interests include research into Bayesian statistics, interactive data analysis, and the application of statistics to problems in business, military, educational, medical, and legal areas. His studies of various topics in statistical research have appeared in a number of professional journals. Together with James H. Lorie he wrote Basic Methods of ***Marketing Research*** (1951) and co-authored ***Statistics: A New*** Approach (1956) and ***The Nature of Statistics*** (1962) with W. Allen Wallis. His ***Conversational Statistics*** (1974) is a well-received textbook currently in use throughout the country.

In addition to his work as a statistical consultant, he is a Fellow of the American Statistical Association (ASA) and associate editor for applications for the Journal of the ASA. From 1973 to 1978 he served as a member of the ASA advisory committee to the U.S. Bureau of the Census. In 1959-60 he held a Ford Foundation faculty fellowship. He is a member of Beta Gamma Sigma and Phi Beta Kappa.

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Statisticians Can Matter

INTRODUCTION

My title was suggested by George Stigler's insightful and (to me) disturbing essay, "Do Economists Matter?" (1976). Stigler was concerned with the influence of research economists on public policy. The traditional view is that expertise in economic analysis permits economists to make constructive and substantial contributions to policy formation as "friends and guides to the public." Stigler argues that this view is a very substantial exaggeration. What research economists do, he says, is to produce for their market, just as do other groups in the labor force. Outside of teaching, the market demand for research economists is derived mainly from interest groups who seekspokesmen to provide rationalizations for policy positions that have been reached on the basis of considerations other than those of disinterested economic analysis. I shall call this market role "advocacy."

Stigler cites the common tendency for both policy makers and the general public to disregard technical economic advice, even about issues on which economists are largely agreed, such as the desirability of free trade and the undesirability of minimum wages or maximum interest rates. He mainly rejects the explanation that "the public does not understand . . . [economic] arguments and therefore does not understand its self-interest" and the closely related explanation that "self-seeking special interests . . . suborn the political process and muddy the public understanding." In rejecting the notion that it is the difficulty or abstraction of economic reasoning that leads to resistance to the advice of economists, Stigler points to the ready acceptance of the findings of natural scientists, where the underlying reasoning is even more complex and abstract. His

alternative view, subject to empirical investigation along lines suggested in the essay, is that the behavior of the economic profession is to be understood in terms of market processes.

I am sympathetic with Stigler's assessment of the impact of economic analysis on policy formation and with his emphasis on market forces in the determination of what economists do. It would not surprise me if further empirical support, beyond that sketched by Stigler, were forthcoming for these positions. But I am unconvinced by his dismissal of consumer ignorance of economics and of difficulty with abstract reasoning as explanations for the current situation. His major explicit argument is that economists are at a comparative disadvantage in persuasion relative to natural scientists. This argument does not support his rejection of the optimistic view that "eventually . . . [the] retarded public can be taught at least the elementary lessons of efficient economic life." However, Stigler does not mention the really disturbing argument against the view of perfectibility of the public: retard dation has persisted for generations in spite of the efforts of academic economists to remedy it by their teaching.

Since my primary professional allegiance is to statistics rather than to economics (where I qualify only as a serious amateur), I shall explain my position mainly in the context of statistics. Since I am in a graduate business school, I shall switch the focus of application from public decision making to private decision making within business firms. Yet, I believe that similar issues about the relationship between the expert advisor and the ultimate decision maker will arise in the context of statistical analysis for business decisions. The main difference is that business firms ought to be more interested in good technical advice about decision making since business execu-

tives can concentrate on the substance of the decision rather than the appearances: They must meet profit tests rather than tests of popularity. Further, insofar as economics must, of course, rely on statistics in its empirical work, I believe that my perspective will supply an element missing in Stigler's argument.1

In considering statisticians rather than economists, I shall not follow Stigler's route and deal only with research professionals. Rather, I shall include the entire range of statisticians from the seasoned professionals down to the former student of a single introductory course trying to draw on something once learned and now half forgotten that may be helpful in a current assignment. I do this because, as I shall explain in detail, only a tiny fraction of statistical analysis is-or is likely to be-carried on by professional specialists.

I am willing to accept the view that these statisticians are subject to market forces and that by and large business is spending on statisticians about what it thinks statisticians are worth. But if managers could really measure (statistically, of course!) the marginal product of the statistical services they purchase, would they want to buy more or less? Would they be satisfied with the kinds of services now offered or would they deem it advisable to search for something better ? Is statistics a tool that under some circumstances can or should be applied

1 In private correspondence, George Stigler has brought out an important point of contrast between statistics and economics. He mentions the distinction between those scientists who tell you what goals you ought to seek (the role of normative economics) and those who tell you better ways to get to given goals (the role of positive economics). Statistics, he says, has the latter mission, whereas a part of economics is concerned with normative questions. Thus statistical evidence can convince a smoker of the trade-off between the pleasure of smoking and the enhanced risks of disease, but he may elect to continue smoking if he accepts the trade-off. His decision should not be interpreted as a rejection of statistical advice.

on a do-it-yourself basis? Stigler's essay encourages examination of these questions.

Some Casual Empiricism

My impressions about the role of statisticians in business decision making parallel those of Stigler about the role of economists in the formation of public policy. I do not see the statistician very often serving as friend and guide to the manager. Stigler's first-line defense of his position was easily derived from the observed divergence between public policies and the conclusions of economic analysis. My task is much more difficult and I have to rely on a variety of impressions and anecdotes that bear on various aspects of the question. Fortunately, my impressions are uniform, suggesting uinformity of the population sampled. If the population is uniform, statistics tells us that casual samples of small size can give accurate information.

the needs of practical application. Most elementary and intermediate texts, even in business statistics, treat both theory and application in the context of the simplest of models, that of random disturbances. Yet much of the vital data generated by business firms, and most of the external data on which businesses must rely, refer to time series in which the disturbances are not random. Modern developments in time-series analysis, however, are scarcely reflected in these texts. The few time-series topics taken up are of dubious value; students can learn about trend fitting, for example, but not about differencing of data to achieve stationarity.

I chose time-series analysis as one example of many. One seldom finds much treatment of methods of probability sampling of finite populations beyond simple random sampling and possibly stratified random sampling. The

important ideas of experimental design and of quasi-experimental design receive at best limited treatment. Little if anything is said about methods of model identification, diagnostic checking, and cross-validation. Heavy emphasis is placed on testing of null hypotheses, which is seldom appropriate in business contexts except as a means of diagnostic checking of models. Little of a constructive nature is said about the difficult problems of communicating the results of statistical analyses. Problems and exercises rarely lead the student to grope with difficulties of handling real data.

My aim is not to criticize the authors of elementary and intermediate texts. After all, they are producing for their market. But if the most useful statistical techniques remain largely hidden in advanced and specialized treatises, the journal literature, or in the oral tradition of a few wise practitioners, it seems unlikely that they being widely used in practice.

There is hardly ever a professional statistician around when you need one. Many texts (and presumably courses) are based on the premise that statistical methodology is too extensive, too advanced, or too mathematical to be given adequate treatment in early courses. They, therefore, try to focus on the student's needs as a consumer of statistics rather than as a producer. One hope is that the enlightened consumer can recognize the need for professional assistance once he gets out of his depth. (I am reminded how often Ann Landers suggests that her correspondents should seek professional help in coping with their problems.)

I am not confident of the ability of the professional statistician, however able, to handle deftly all the tough questions that might be referred to him. The overriding problem, however, is that there is hardly ever a professional

statistician around when you recognize the need for one. I have often observed even large companies that cannot find required technical expertise in statistics anywhere in the ranks of their employees. (Sometimes, largely unknown to management, there may in fact be a professional statistician lurking in some corporate backwater.) I know of only a handful of full-time consulting statisticians of professional caliber, and the ones I know are often concerned with specialized applications in technology, such as the design of industrial experiments, rather than with the application of statistics in the mainstream of decision making. As a part-time consultant, I have noticed that much of the demand for my services arises from adversary legal or prelegal proceedings-where one expert is needed to fight an expert on the other side-rather than from decision-oriented problems within the firm. This is, of course, the advocacy role.

Statistical instruction (as other forms of instruction) leaks away quickly. If professional statisticians are neither readily available nor in great demand for decision-oriented applications, one might look to people less thoroughly trained than professionals but who fit comfortably within my broad definition of statistician. As an example, consider the design of a complex sample survey by probability sampling methods. There are many excellent texts on probability sampling; no single area of statistical knowledge seems so well served by good texts. Many thousands of students have been exposed to courses based on these texts. Yet in the Chicago metropolitan area there is scarcely anyone outside of academic institutions, and only a few within them, with the technical background to design a complex, or even not-so-complex, probability sample.

Part of the problem of the leaking away of statistical knowledge may arise because of low

demand since what is not used is easily forgotten. Few users of statistics in, say, marketing, appear to understand the advantages of probability sampling or even to contemplate the use of probability sampling in market surveys. The merit of a proposed sampling design is often gauged simply by the total number of interviews, without regard for selection methods or treatment of nonresponse.

It is much easier to collect misuses of statistics than good constructive applications. When Allen Wallis and I were writing an elementary statistics text some years ago, we were able to prepare a long chapter on misuses of statistics by using only a small part of our stock of examples, a stock that had accumulated almost without effort since students were able easily to find illustrations for us. In the textbook literature, by contrast, there are few adequately documented, interesting, important good examples. Many of the main illustrations in texts are based on artificially contrived data, and I do not believe that this phenomenon is explained adequately by the desire to avoid complexity in exposition. A few years ago I was looking for an application of the linear discriminant function (a technique that has had some currency in business practice, especially in the selection of good credit risks) to a real problem. I needed the original data so that I could illustrate the use of diagnostic checks. Two days of browsing yielded only one good candidate. But when I analyzed the data, they flunked the standard diagnostic checks; the linear discriminant function was not really appropriate to the data. Fortunately, I finally did find an example, but it came from an almanac rather than from a statistics text.

I have found surprisingly little interest by business firms in computer implementation of statistical tools of business analysis. Contacts with students and graduates of our Executive

Program at Chicago suggest that few companies have very satisfactory facilities for statistical computation, either in house or from outside services, especially in the interactive mode. One manufacturer of minicomputers has apparently found that good statistical software has been only of minor help in promotion of sales. When I talk with data processing people in business, I sense great interest in management information systems but very little interest in statistical and other analytical tools for exploiting these data bases. These bases are thought of as sources for reports but not as objects of statistical analysis.

dency to use statistics poorly in the scholarly literature *of business.* What is needed is properly focused, incisive data analysis. What is too often found is mechanical testing of often irrelevant hypotheses without much diagnostic checking of the implied statistical models.

Decisions that I know about in business seem rarely to be made with much reliance on good statistical analysis, even at the level *of* ***"commonsense statistics."*** An anecdote will illustrate my point. A few years ago, a publisher's representative for a leading publisher of technical books, well-known for its series of statistics texts of distinction, asked my opinion about a manuscript. The manuscript was an excellent exposition of new methodology in time-series analysis, by Charles Nelson, later published (with success) by Holden-Day, Inc. under the title ***Applied Time Series Analysis*** *for* ***Managerial Forecasting.*** Since the manuscript was not a conventional one, the representative was anxious to know how it would be received in the classroom. I assured him that it was well received at Chicago. Even if there might be some resistance because of unconventionality, I said, the book was solid and offered techniques that would be widely ap-

plicable in business practice. "Why," I said with what I thought was a decisive insight. "your company could use these techniques." Without hesitation he replied (sadly, I am glad to report), "Our company never uses statistics."

Why Is Statistics Apparently Little Used in Business?

If you will at least tentatively accept the conclusions of my casual empiricism, I think that you will be curious about possible explanations. I suspect that Stigler would resist any attempt to explain my observations by appeal to the difficulty and abstractness of statistics. He would, I think, remind me that the natural sciences are readily acted upon by decision makers. It does superficially appear that the natural sciences play a fundamentally more constructive role in decision making than do "decision sciences" like statistics and economics. One thinks almost automatically of the decision by President Roosevelt, made after advice from distinguished physical scientists, to launch the Manhattan project in the early 1940's.

The trouble with Stigler's assertion about the natural sciences is that it is true only within a limited domain, that of certain applications of technology and engineering. There is nothing magical about "hard" science as an intellectual discipline that commands acceptance for decision making. The Manhattan project, for which there was little direct technological precedent, is not typical. Consider the following examples, in which natural scientists receive about the same reception as do economists or statisticians: (1) It is proposed that seeding the nucleus of a developing hurricane will tame the hurricane. (2) It is claimed that smoking enhances the risk of heart disease. (3) An analysis sugests that a proposed nu-

clear power plant will (or will not, if you choose) have an adverse impact on the environment. (4) A study suggests that supersonic transports will (or will not) seriously deplete the ozone layer. (5) It is recommended that air bags be installed in all cars because the expected number of lives saved is claimed to be large. (6) A nutrition expert suggests that emphasis on meat and dairy products in American diets is bad for the health. It matters little whether natural scientists are in substantial agreement (as on (2)) or are divided into camps of opposing advocates (as on most of the others).

of *Case Histories*

The scientific background of the expert advisor to the decision maker is not of itself an important predictor of the persuasiveness of the advice. The key is rather the kind of evidence that decision makers (and the public at large) find convincing. By and large people are convinced by concrete, tangible, easily grasped cases, a kind of evidence for which refined statistical analysis can be unnecessary. (Of course, often such cases do not support the conclusions to which it is so easy to jump.) It is much harder to grasp and to believe the seemingly abstract, typically anonymous, evidence that requires careful statistical analysis. Which is likely to be more convincing to a congressman contemplating proposed legislation of restrictions on sales of handguns: a careful statistical study estimating the expected number of lives that could be saved, or the assassination of Robert Kennedy? Moreover, if there is a conflict between the apparent import of case histories and the conclusions of a statistical analysis, the former tends to be more persuasive.

Technologists are listened to when they have produced tangible evidence of results, at

least in areas closely related to the current problem on which they are giving advice. By tangible I mean mainly things that work, such as automobiles, storm drainage systems, or handheld calculators. A background of successful basic research without such successful case histories is unlikely to suffice. Thus we see that automobiles are produced and that they run, and also that improvements are made from time to time. If an automotive engineer proposes a program to develop some specific improvement, his management has this background very much in mind and will take the suggestion seriously. They may be more skeptical about how long the development program will take or how much it will cost, because on these questions the evidence is less clearcut

Consider by contrast decision making about the regulation of supersonic transports. There are likely to be no case histories, and a difficult and abstract statistical analysis, buttressed by equally difficult and abstract theoretical analysis, may be needed to say anything at all about effects on the ozone layer. Even after the decision is made, there will be no dramatic evidence to confirm or refute its wisdom. The attitude of the decision maker toward the technologist changes radically. The technological arguments may be virtually ignored. Something of this sort seems to happen in everyday life when people make decisions about dietary balance. Since few variations within the usual caloric limits of American eating patterns will have an immediate and clearcut effect on health and well-being, all kinds of nutritional superstitions flourish in spite of a measure of scientific consensus among nutritionists.

One referee has suggested that it is the element of uncertainty rather than the difficulty or abstractness of reasoning per se or the scientific background of the advisors that leads de-

cision makers to resist scientific advice. He points out that deterministic linear programming (LP) has apparently been more readily accepted by managers than has statistical decision theory. "When you use LP and are confident that the LP model is a good approximation to reality, you know you will receive the best possible payoff without any ifs, ands, or buts. When you use statistical decision theory, you achieve the best expected payoff (or utility), but the actual payoff may, by the luck of the draw, be terrible!" I regard uncertainty as perhaps the most important, but not the only, component of difficult or abstract reasoning. Deterministic theory, for example, is an important foundation of the opposition of economists to minimum wage laws or tariffs.

The same referee points out that the educational process works to make it easier to turn out genuine experts in the subject matter content of natural science or technology than in the methodology of statistics. For example, there is emphasis on hard facts from early stages of schooling, but the idea of probability and uncertainty comes late, and often superficially, if at all. This comment leads naturally to remarks on the difficulty of delegation of statistical analysis.

Difficulty of Delegation

Still, since businesses are interested in profits, it should be possible to convince some of them that statistical analysis, however abstract it may appear, offers a way to improve profit prospects. But a new difficulty can then arise. The use of the statistician requires hard thinking and effort by the decision maker, thinking and effort that cannot be delegated easily. The formal structure of statistical decision theory makes clear that assessments of probabilities and of preferences (utilities) are required, and these must come in principle from the decision

maker, not the statistician. Further, creative thinking is needed to formulate decision problems in operational terms, and statisticians rarely have the background to do this unaided.

In technology, it is easier to delegate. The decision maker can specify performance standards, at least in general terms, and then rely on the technologist's hard thinking. Remember that most of us can drive cars tolerably well without much understanding of how things work under the hood.

It is not possible to specialize fully in statistics (or in economics) as it is in technology. The president of a company can hire physicists and not know anything about physics himself. Can he hire someone to do all his statistical reasoning? Of course not, statistical reason ing is inherent in rational responses to imperfect knowledge.

EXHORTATION

I have claimed that statistics is less, and less well, used in business decision making than its potential would lead statistical enthusiasts to expect or to hope. I have argued that the abstractness of statistical reasoning and the difficulty of delegation of statistical analysis are part of the explanation. To this extent, there can be said to be underinvestment in statistical analysis by comparison with the state of affairs that would prevail if only decision makers could be better educated about statistics.

At the comparable stage of Stigler's development, he could simply call for empirical research to document his impressions, since he largely denied that the difficulty of economics was an important explanation for its small impact on policy formation. I too can call for empirical research. Why is it that some parts of professional statistical knowledge are more widely practiced than others? What are the reasons (besides age) for differences in dis-

semination of knowledge? Are the lags in application of statistical knowledge really unusually long in comparison with those encountered in other technical fields?

But my main emphasis will rather take a hortatory direction to suggest how statisticians, and especially statistical writers and teachers, might palliate some of the common difficulties in learning, believing, and applying statistical ideas. Although I do not have much hope for exhortation, since the undesirable state of affairs has persisted in spite of a great deal of exhortation, I shall begin there. Then I shall point out certain technological developments, especially those connected with interactive statistical computing, that give more solid hope for progress in the future.

The exhortation is for teachers of statistics, including most surely myself. We must think of the statistician not as the professional but rather as anyone who uses statistics in problem solving or decision making. This includes essentially everyone, for statistics can be thought of as the process of learning from experience. (Just as many people are unaware that they have been speaking prose all their lives, so few are aware that they are practicing statistics!) I have asserted that there are and will be few professionals by comparison with the potential for decision applications of statistics. Decision making entails detailed subject matter background that is hard to communicate to statistical consultants, and the team relationship of statistician and subject matter specialist is a rarely seen luxury. Hence we teachers of statistics should not think of our elementary courses primarily as consumer courses designed to teach appreciation of statistical ideas and ways of working with the professional statistician. Even though this consumer role is important, its overemphasis tends to create a passive attitude toward statistical thinking

and even to encourage a shallow cynicism about statistics, since it is much easier to criticize bad statistics from the sidelines than to do good statistics, on however modest a scale. We should think of our students as potential producers as well as consumers of statistics, where by "producer" I mean a serious user of statistical thinking in decision making. If this sounds quixotic, remember that few statisticians, no matter how well trained and experienced, feel that they can really do justice to most applications.

We can often work examples into our teaching to bring out the possibility that explicitly statistical thinking can give insight into the limitations of more informal modes of decision making. For example: (1) It has now been established for some time that the logarithms of stock prices and other prices on organized commodities markets follow approximately a random walk through time. This implies, among other things, that technical analysis and charting are useless. (2) A substantial amount of evidence has accumulated that very simple statistical selection procedures based on regression do a better job in the selection of, say, students than do the informed judgments of experts, such as admissions officers and deans of students. However, it may be possible to improve on regression by statistical calibration of the impressions of the experts (Pankoff and Roberts 1968). (3) Loose, qualitative thinking can be made precise by statistical analysis. For example, there is considerable recognition that short-term treasury bill rates are a leading indicator of returns on stocks. In 1975, I guided students through a regression analysis of an index of monthly returns on the New York stock exchange on one-month treasury bill rates; this led to explicit and simple regression models that seem to validate the common belief.

Insofar as it is possible, we should introduce something of a "cookbook" flavor into our textbooks. Cookbook is usually a term of opprobrium for a statistics text since statisticians, like other academicians, have a bias in favor of encouraging students to think for themselves. It is good to encourage students to think, but thought is costly and can be economized with benefit for use on the really hard tasks, such as the formulation of the statistical problems. Note that engineering texts often bear close analogy with cookbooks. They offer tried and true procedures that work if you follow the directions.

The older statistical cookbooks were so named because they emphasized details of execution of computational procedures on desk calculators. In precomputer times, this approach was understandable because there was no other way to do the computations needed for practical implementation of statistical ideas. With the advent of computers, this aspect of statistics can be automated and need take up little space in the textbooks. And to some degree, even model identification and diagnostic checking can be reduced to cookbook treatment. Automation of statistical methods is not intrinsically bad.

We should above all rethink what students most need to know about statistics in order to have a fighting chance of making some effective use of the subject. Since the mathematical foundations of statistics are essential to the structure and since mathematics is prestigious in intellectual circles, there is a tendency to devote too much time to mathematics at all levels of instruction except the most advanced, which is almost by definition mathematical. It is easy for the student to lose sight of the central concept of statistics as a method of systematic reasoning about uncertainty, which is ultimately aimed at better decision making.

The mathematical foundation is important to the nonprofessional statistician precisely to the degree that it helps him use the tools of statistics. The essence of statistics is only incidentally mathematical. It embraces the systematic formulation of decision and inferential problems, including the recognition that there is a problem; the formulation of tentative statistical models to guide data analysis, which requires understanding of the assumptions or specifications required for proper application of the models; and the diagnostic checking and fitting of these tentative models. In the process of teaching these things, we need to stress real problems, not finger exercises designed for easy arithmetic. Real problems usually have diverting features that complicate analysis, but students need to learn this early and to acquire some notion of how to cope with diversions. Further, the tools of statistics given highest emphasis should be those of highest potential in the student's field of application. In business, we are fortunate that a relatively simple body of tools subsumed under the general term regression is so widely applicable in practice. Box-Jenkins time-series methods, for example, can be regarded as a slightly more sophisticated brand of regression than elementary least squares that can be taught as an easy extension. Students can thus be brought into contact with the time-series applications so important within the firm.

If, in the process of giving the highest priority to the most useful statistical tools, traditional topics such as the binomial distribution and tests of hypotheses are squeezed out or highly compressed, the students will still be ahead. In view of the enormous discrepancy between the coverage of traditional texts and the needs of practice, drastic rather than creeping revisions are in order.

Perhaps this is already too much exhorta-

tion. Can exhortation help? I have been exhorting myself along these lines for many years. The results were undistinguished until the advent of interactive computation in 1971 at the Graduate School of Business of the University of Chicago. Signs of improvement were soon discernible, and for the first time I dared to hope. Robert Ling and I have written an account of this development, as it related to statistics, under the title, "IDA: An Approach to Interactive Data Analysis" (1975). Even those statisticians fortunate enough to use interactive computing are still only beginning to make full use of it. Even better results lie ahead. I will say no more about details, but I will attempt an overview of the relationship of the computer to my central theme.

Reason for Hope: the Computer

If I were bold enough to assess the impact of the computer up to the present time, I am afraid that my verdict would be equivocal. The old computing tedium is gone, although this gain has been partially offset by the frustrations of unfriendly computing systems oriented to the convenience of the suppliers rather than the users of computing services. Computing power has increased to levels undreamed of when I first started doing statistics. But, in statistical computing as in many other applications of computing, the main thrust of automation has been to perpetuate the old approaches to the subject with a reduction of the unit cost. This has led to statistical computing packages that have made it possible to do the things done in the textbooks that I have criticized, and on such a huge scale that users are often overwhelmed by printout. The old drills on desk calculators at least insured some knowledge of statistics before results could be obtained and had the advantage

of bringing the student close enough to the data to get some feeling for what he was doing.

As suggested at the end of the last section, there are now encouraging developments in computation that have been successful on a small scale and that portend much more.

the power and economy *of* ***interactive computing (including fast-turnaround batch) and we have seen the beginnings*** *of* ***good statistical applications software to exploit this new capability.*** In the process of facilitating statistical computation, these developments play the more important role of facilitating statistical thinking. The user can be encouraged, indeed almost forced to think about what he is doing New teaching approaches are beginning to appear both to understanding of theory and to a deeper insight into data, and they are applicable both for elementary and advanced instruction. Much greater depth and breadth of coverage of statistical techniques within the time constraints of courses have become possible.

2. There has been rapid improvement in methods *of* ***display, especially graphic,*** *of* ***the output*** *of* ***statistical analyses.*** These developments not only aid statistical teaching, but they encourage geometrical modes of thinking that are, for many, natural and powerful, and they make communication of statistical conclusions more effective.

3. There is increased interest in the development *of* ***management information systems.*** As these systems come into being, the payoff for good statistical analysis will be substantially increased, since needed data will be made more accessible.

In the absence of these developments, I would have called this essay, "Statisticians don't matter much," if I would have at-

tempted it at all. As it is, I do not believe that my title, "Statisticians Can Matter," is wishful thinking, self-deception, or narrow special pleading.

A second referee accepts my casual empiricism about the underutilization of statistics but feels that the problem is not curable by the *deus ex* machina of interactive computing. He argues that the difficulty of statistical thinking has deep-seated causes that are most clearly revealed by "persistent illogic (misuses if you will), like quoting the wrong ratio in a 2 X 2 table," and points correctly to obstacles that deter implementation of good interactive computing. I am well aware of the latter; hence I have pointed to the computer only as reason for hope. As to persistent illogic -violations of elementary common sense-I am convinced that the problem cannot be cured successfully and lastingly by presentation and discussion of horrible misuses of statistics. It is only by motivating students and users toward constructive applications of statistics that we can get them to take statistics seriously enough to see that good statistical logic is worth striving for.

Discussion

I have contended that up to the present time, statistics and statisticians have had a relatively small impact on decision making in the business firm. Although I readily concede that the market for statisticians as advocates of positions and rationalizers of conclusions is large and important, I think that demand for statisticians as decision makers and consultants to decision makers will expand because of technological developments in interactive computing.

One major resistance to the use of statistics in decision making stems from the difficulty of many people in appreciating the force of an

abstract statistical argument by comparison with a vivid but often misleading case history. In those areas of statistical applications where the forecasts implied by statistical studies can be checked, it would be useful to attempt systematic collection and validation, and to contrast forecasts made by statistical methods with those made by less formal methods. Recent developments in forecasting of business and economic data make this methodology especially attractive to statisticians in business firms who desire to demonstrate the value of their knowledge, and interactive computing is an excellent vehicle for the demonstration.

I have concentrated my attention on statisticians and decision making in business firms. I have had some experience with statistical applications in areas outside of business. I would conjecture that broadly similar essays could be written about almost any area of application. Statisticians will have an exciting opportunity and challenge in the years ahead to see if the technological miracles of computing can be effectively exploited.

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