

responses. Hamaker argues that this activity goes beyond the legitimate bounds of a statistician.

If the statistician distinguishes between established facts and deductions and opinions, then directly related judgmental inputs to the decision maker can be made. The same would be true of lawyers tendering advice. They can state the law, but then legitimately give their opinion on the likely legal consequences of alternative courses of action, where the law does not cover the situation in a black and white fashion. It is worth noting that lawyers are not inhibited from becoming members of Boards of Directors; they are able to walk the tightrope between their role as a lawyers and their role as a decision maker. If statisticians feel inhibited from going any further than the preparation of data and their analysis, there is a danger that their role will increasingly be perceived as that of a technician rather than as an executive and they will be marginalized. Widening does carry some

implications. For example, I believe that statisticians ought to have a basic knowledge of accounting and cost control processes, since so much statistical data is used as a background for financial calculations.

In general, the compartmentalized roles of professionals are breaking down, with far more cross-activity taking place. Deregulation in U.K. and Europe has seen to this, although there is a long way to go to integrate individual professions. It is unclear, under the new regime, how professional standards can be maintained and, indeed, enhanced. Statisticians do not have statutory regulation as is the case with accountants, doctors, lawyers, etc. There is a need for a self-regulating and monitoring arrangement so that those who have need for effective statistical advice can be aware of the standing of the individual. Whilst statistics should become a way of thought for all well educated persons, an important and continuing role remains for the expert.

Comment

John Neter

Harry Roberts has prepared a most interesting and provocative essay on applications of statistics in business. Roberts is concerned about the extent of statistical applications in general, and in business in particular. Other professions also are concerned about the relatively limited uses of their methodologies. The professions of management science and operations research are cases in point. But Roberts' main purpose is not to dwell on the current situation of relatively limited applications of statistics to business problems. Instead, Roberts' intent is "to place major emphasis on constructive suggestions for improvement of business practice by more effective use of statistics."

In proceeding from an assessment of the extent of current use of statistics in business to a consideration of means of improving business practice through an increase in the use of statistics, Roberts wanders on a somewhat rambling and repetitious path. Nevertheless, I am delighted that *Statistical Science* has provided this opportunity to a senior statistician to speak from his heart and to be able to make personal reflec-

tions from his many years of teaching and consulting experience without being confined to a tightly written scientific style.

Roberts paints his themes with broad brushstrokes and I do not wish to let quibbles with some details obscure my comments on Roberts' major themes. I shall therefore mention just a few instances where I have some disagreements with, or questions about, Roberts' details.

I concur with Roberts' assessment that statistical applications in business today are far below their potential level. However, with all of the developments in the use of statistical sampling in auditing that have occurred in recent years, I would not say that use of probability sampling in auditing is relatively rare. I certainly would agree that probability sampling in auditing still is utilized far less frequently than it might be.

In his discussion of the use of statistics to study cause and effect in business, Roberts cites observation after direct management intervention designed to improve process performance as an experimental study. Clearly, this would not be a formalized experiment where treatments are assigned randomly to experimental units.

When discussing expert systems in statistics, Roberts is concerned that these systems will duplicate the

John Neter is Professor Emeritus, Department of Management Sciences and Information Technology, College of Business Administration, University of Georgia, Athens, Georgia 30602.

expertise of a statistician in the use of sophisticated methodology that may be unnecessary for the solution of practical problems. This fear would be needless if the expert system duplicates an expert like Roberts who begins with basic tools to see if they are adequate for the problem.

I conclude this list of minor quibbles by noting that Roberts, in discussing the alleged serious misunderstandings of statistics in Section 3.6 and in the summary, never lets us know who has these misunderstandings.

Let me turn now to Roberts' major themes. He performs a most useful service in reminding statisticians that statistics is not the cure-all for every problem in business. Every profession tends to be self-centered, and statisticians are no exception. In fact, Roberts occasionally lapses into egocentricity, as when he says that "statistics is the glue that binds together the functional areas of business." One could make convincing arguments that management information systems and informal communications processes also are candidates as the "glue." Indeed, the "glue" is a composite of many elements, including statistics.

In this vein, Roberts reminds us that statistics plays a key role, but not the only role, in quality improvement programs. Beyond that, he notes that "the quality ideas are an essential component, but only one component, of new developments in the theory and practice of manufacturing . . . and in business management more generally." In a series of provocative quotes from Schonberger, Roberts sketches the modern emphases on data recording, data analysis, and problem solving by line workers, where basic statistical concepts and methods play a key part.

Roberts stresses that business problems must be solved by considering costs and benefits, and therefore that testing of sharp null hypotheses is rarely relevant to the manager who makes the decision.

As Roberts develops these points, one cannot help reflecting on the need for statisticians in business to be team players to be effective. Business problems are often interdisciplinary in nature. The problems frequently have an important statistical component, but the statistical methodology and analysis need to be shaped by the problem in its full complexity if they are to be relevant. I have commented on this elsewhere (Neter, 1986).

I find Roberts' essay least satisfying in the area that he intended to emphasize the most: how to improve business practice by more effective use of statistics. He discusses the need for a proper organizational culture, citing the works of leading writers in the field of quality improvement, such as Deming, Juran and Ishikawa. However, Roberts has little to say about how to achieve an appropriate organizational culture.

Roberts also discusses the need for parastatisticians in a business organization. I concur entirely with Roberts' assessment that effective implementation of statistics in business will require parastatisticians who are placed strategically throughout an organization. But Roberts says little about how these parastatisticians are to be developed in a firm and how they are to be maintained. I have seen instances in several firms where key parastatisticians were not replaced, upon being moved to higher management positions, and did not have the time to continue to function as parastatisticians.

Even more important than the need for parastatisticians is the education of future business managers. Roberts dismisses this subject by expressing little hope for help from academia because of the current incentive structure in universities. Yet it is precisely by appropriate education of the future business managers that we can help develop persons needed for the kinds of organizational cultures espoused by Roberts and others, cultures that will support and encourage decision making based on factual information and that will emphasize the roles of all persons in an organization in improving the quality of the organization's processes. The time to instill in future managers the habit of approaching business problems in an interdisciplinary fashion, and to provide them with the statistical concepts and tools to make effective use of data, cannot be early enough. If, as Roberts notes, all persons in a business organization need to make decisions based on factual information, they must be educated so as to seek out relevant data, on the basis of which they can make decisions objectively, and they must be trained to think statistically.

These requirements place special responsibilities on the faculties of schools of business and, in particular, on the statisticians in these faculties. First, statisticians will need to reexamine the objectives of the statistics course required of students in business administration. If, indeed, a basic objective is to instill in the students the ability and habit to think statistically, and I believe this should be a key objective, we need to define more precisely what we mean by statistical thinking. In addition, we need to determine how this way of thinking can be taught most effectively. Some years ago, several colleagues and I (Chervany et al., 1977) considered how to operationalize the concept of statistical reasoning so that measurements can be made to ascertain how effective the statistics course has been in achieving its objectives. Much work remains to be done in defining the key ideas underlying statistical thinking and exploring how they can best be taught.

Second, faculties of schools of business will need to reexamine the curriculum for business students in its

entirety. In reading Roberts' essay, I was reminded of the fact that all of the concepts of quality improvement and all of the emphases on interdisciplinary problem solving mentioned by him are applicable to education. Faculties in schools of business are also dealing with processes that can be, and need be, improved based on factual information. Improvements in education, as in business, require teamwork and a point of view that focuses on the problem as a whole.

In my opinion, one of the biggest handicaps to substantial improvements in business education is the current emphasis on disciplines. This emphasis, together with strong disciplinary departments in many business schools, frequently have led to curricula that are made up of compartmentalized courses, with at most one or two capstone courses intended to provide integration.

This fragmented approach to curriculum construction is contrary to the message presented by Roberts that statistical thinking must permeate an organization and that business problems are interdisciplinary problems. While Roberts is writing from the perspective of statistics in business, these ideas extend to curriculum construction for educating future business managers. The interdisciplinary nature of business problems requires an interdisciplinary approach to the construction of the curriculum for business students. Many business problems involve several functional fields, such as marketing and finance, and may require optimization techniques developed by management scientists, statistical analyses for key portions of the

problem, and communications experts and management information systems experts for implementation. Thus, it is parochial to believe that statistical thinking can and should be taught solely in a single statistics course, anymore than that the ideas of quality improvement should be taught in a single course on quality improvement or that communications skills should be taught in a single course in communications.

We academicians in business schools claim that we have the tools for businesses to solve their interdisciplinary business problems, but we are reluctant to apply the same tools to our own business, that of education. I agree with Roberts that the current structure of incentives in universities is a major deterrent to quality improvement activities at universities. But that is no reason to give up before an effort has even been made.

The improvements I am thinking about cannot be made by statisticians by themselves, anymore than by accountants or management scientists by themselves. We statisticians need to talk not just among ourselves, but with our colleagues from the other disciplines in business schools. It is my hope that Harry Roberts, together with other statisticians in business schools, will expand their efforts to work with business school faculty members from other disciplines in bringing about the needed changes, so that the business managers of the future will have the outlook and habits of statistical thinking necessary to improve business practice.

Comment

John W. Pratt

My only significant disagreements with Roberts concern Occam's razor and time series. Also I am more pessimistic than he is about the corporate and educational climate for statistics. Otherwise I am in broad agreement with this thoughtful views and remarks, and nothing I say should be interpreted otherwise, though I won't calibrate my reactions on the scale from "Amen" to "Hear! Hear!"

Occam's razor (parsimony) as discussed here, and by other outstanding practical statistical philosophers,

cuts too much and too indiscriminately by far, I believe. Consider eliminating "unnecessary" variables in regression. The better the included variables can proxy for them, making them more "unnecessary," the more the included coefficients will be affected and the more the standard errors of these coefficients will be reduced. These are important and unsignaled biases when the coefficients are interpreted as effects. Causal interpretations of nonrandomized data will be completely vitiated if parsimonious dicta are followed. Obvious mistakes of this kind will presumably be avoided in practice, but not subtler ones. Witness the plethora of preliminary tests of significance. Even in passive forecasting, eliminating variables can easily

John W. Pratt is Professor, Harvard Business School, Soldiers Field, Boston, Massachusetts 02163.