Comment

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I have thoroughly enjoyed reading David Banks' paper "Is Industrial Statistics Out of Control?". I am currently in academia and have spent several years in industry, allowing me to have some perspective on the topic both from within and outside industry. Much of what Dr. Banks wrote was familiar to me; some of it was new to me. What surprised me was the implication that this article represents the entire role which statisticians play in industry. Dr. Banks looked solely at industry as manufacturing processes, and he reviewed most aspects of statistics as they relate to manufacturing. He reviewed issues of experimental design, control charts, the popular Taguchi methods and so on. I could not agree more with him about the overpopularity of these methods. I myself was surprised when I first understood what they were about, how simple and straightforward they were and the fact that they stemmed from such elementary statistics. However, they have an aura of something fantastically new. Therefore, regarding most of his presentation, other than minor points, I could not but agree. There are some statements that Dr. Banks made that probably could not have been truer. For example, his statement about the Japanese being committed to continual improvement as opposed to the U.S. "home run" corporate strategies. Unfortunately, it is still true now, if not even more true, because corporations feel financial pressures even more so than in previous years. I agree with Dr. Banks that the Japanese success can be attributed to their policy approaches more than their use of one statistical technique or another.

There is a big role of statisticians in industry that Dr. Banks ignored. There is a tremendous role for statistics in the research and development components of industry. It appears that Dr. Banks, and there must be many others like him, perceives that the primary role that statisticians serve in the industry relates to manufacturing. My experience has been that, at least in some industries, statisticians play a much stronger and larger role in the research and development part of the industry than in the manufacturing part. These statisticians, including myself, would definitely define themselves as "industry statisticians" and their primary professional agenda as dealing with "industrial statistics." My personal experience has been primarily with the biopharmaceutical industry in the research and development part. At Merck & Co., which is one of the largest pharmaceutical companies worldwide, there are roughly 70 statisticians. More than 60 of those are in the research and development part, and fewer than 10 of them are in either manufacturing or marketing. I think that the distribution, if not the magnitude, reflects the rest of the pharmaceutical industry. In addition, there are statisticians working at various clinical research organizations who are not formally part of the industry but support this industry also on its research part and not on its manufacturing part. I devote this commentary to describing the work that industrial statisticians involved in research and development do and the areas to which they make contributions.

Statisticians are involved in all phases of the research that occurs in their company. In the pharmaceutical industry, the first step is to come up with a viable compound. Then, that compound goes through laboratory testing, animal testing and finally human testing. The statisticians are involved in all of those phases, and statisticians both in academia and industry have been responding to needs over time to develop new methodologies. Recent examples are a paper on estimation of relative potency (Racine-Poon, Weihs and Smith, 1991) and a paper on simultaneous evaluation of benefits and risks in clinical trials (Chuang-Stein, Mohberg and Sinkula, 1991). In the preclinical or laboratory setting, statisticians are also frequently asked for help in a consulting role that does not necessarily translate into publications, but certainly often involves innovative and thoughtful approaches. These approaches are valued by their colleagues, be they biologists, chemists, pathologists or other professionals. In the clinical phase of drug development, the role of the statistician is very important and the drug cannot be licensed without very heavy input from statisticians. The statisticians support the experimental design of these studies, also known as clinical trials, they monitor their progress from the statistical viewpoint and finally they are responsible for data analysis. Of course, many of these analyses are straightforward and involve only t tests, χ-squares or analysis of variance. But many of them are not and as time marches along, the industrial statisticians develop a variety of new and better ways to deal with analyzing more complex data, more complex phenomena and increasing demands of

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society for both proof of efficacy and of safety. The United States Food and Drug Administration (FDA) is the body that regulates the biopharmaceutical industry and licenses drugs to be used in the market. The statistics world probably owes it to the FDA that their rigor (and conservativeness) has forced the biopharmaceutical industry to use the tools of statistics and, to a very large extent, to use them appropriately, as Dr. Banks recommends. It should also be noted that the statisticians in the FDA are involved primarily in the research and development side of the industry and not in methods to monitor the manufacturing process.

Similar to Dr. Banks' presentation on the manufacturing side, several areas have traditionally been targets of the research of industrial statisticians and several areas are new. Certainly, experimental design is equally important to the research and development side as it is to the manufacturing side. Similarly, research in various types of regressions and in nonparametric methods has traditionally been important. Today, while nonparametric methods are still very popular because of their robustness to assumptions, there are many new methods which are more computer intensive and take better advantage of the data than nonparametric methods. There is substantial research into bioequivalence, longitudinal methods, survival analysis and many others. Related to that, categorical outcomes are also important, in particular to safety analysis, and not outdated as Dr. Banks stated in his education part. Another area of much research, both by academic statisticians and statisticians in the research and development side of industry, relates to missing data, particularly on research on human subjects. There, missing data occur naturally, and it is unavoidable. Its impact on inference is obviously large and must be estimated carefully. Work in this area has been going on for many years [for a nice review of the first generation of research on this topic, see Little and Rubin (1987)] and is continuing today constantly by statisticians all over. Finally, a new area of statistical research is in health economics, which has become popular in the industry for obvious reasons. This is an exciting area where industrial statisticians, both from the research and development and from the marketing group, can potentially collaborate to advance both exciting research agenda and very practical outcomes for the industry.

Contrary to the impression of stagnation one may get from reading Dr. Banks' article, the statisticians in research and development are constantly looking for newer and better ways to do things and to communicate with each other, despite increasing demands on their time and pressures due to the recession. For example, within the last three years, the Biopharmaceutical Section of the American Statistical Association has initiated a publication called the *Biopharmaceutical Report*. In each issue of the *Biopharmaceutical Report*, there is a lead paper on an issue of concern to statisticians in the industry or the government dealing with the industry, in this case the FDA, and discussions from various people in the field. This report is read by the membership of the section. This section has more than 50% industry statisticians and the rest of the membership is from academia and government. Recent articles include a unified approach for safety analysis and statistical education as it relates to the biopharmaceutical industry. The upcoming topic deals with a unified approach to efficacy analysis with a particular emphasis on better graphics. The articles are written often by statisticians from the industry and the discussions are written by professionals from the industry, from academia and government to represent a wide variety of opinions and to stimulate discussion. This particular publication also contains book reviews. Interestingly enough, the last book reviewed was *Design and Analysis of Bioavailability and Bioequivalence Studies* by Chow and Liu (1992), which was not one of the books that Dr. Banks quoted. This topic happens to be important for the entire biopharmaceutical industry and frequently for researchers outside the industry dealing with more than one source for a drug.

Another role that statisticians play in the industry is an education role to nonstatisticians. In response to Dr. Banks' question "Is industrial statistics out of control?," from the aspect of the education of other members of the industry, too little is done, and the answer is "yes." Statisticians prepare and give a variety of courses to educate their nonstatistician counterparts, be they physicians, data managers or other people in the drug research and development process. These courses, if put together well, are generally extremely well received, popular and are in more demand than the statisticians usually can meet (Bradstreet et al., 1992). These efforts should continue, and the more the better, as they improve the subsequent quality of the research in general by strengthening the statistical processes.

I believe it is important for us as a fairly young and already diverse profession to communicate to each other what we do and why, and Dr. Banks' article is an important step in that direction.