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Three Statistical Business Simulations

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Abstract

The aim of this paper is to draw to the attention of statisticians teaching business students three substantial computer simulations, the single objective of which is profit maximization. It is believed that in pursuing this purely business objective, students gain a better understanding of the need for and utility of statistical methods for research, analysis, and forecasting. The full text of these simulations and the associated computer programs, teaching notes, and sample student responses may be freely downloaded and used for classroom purposes.

1. Background

1 Among the many fields of study where statistical methods find applications is business, and business students constitute a large proportion of those receiving instruction in statistical methods. Some believe that this audience tends to be a reluctant one, captured as it were in compulsory business statistics courses, and likely to be considerably smaller if these courses were to become optional. Business students often protest that the traditional business statistics course, with its emphasis on probability theory, special distributions, sampling with replacement from normal populations, tests of hypotheses, confidence intervals, and the classical linear model, does not appear to address any recognizable important business problems.

2 One reason for this perception may be that the course does not seem to speak the universal language of business -- profit. To business students and practitioners alike, profit (interpreted broadly as the difference between revenue and cost, between reward and effort in the long term) is the driving force and profit maximization the almost universal business objective. How, one hears being asked, does statistics help pursue this objective? Of what utility is knowing how to perform, say, a test of equality of means of two normal populations at the five percent level based on a sample with replacement?

3 Such questions were indeed raised from several quarters in recent debates that led to a major revision of the MBA program at York University, one of the victims of which was the traditional business statistics course. The debates centered on the extent of the compulsory part of the program in general, and its allocation among competing fields. Some faculty members were not averse to a program in which statistics had no share at all of the compulsory curriculum. In the end, a shorter and broader course providing an introduction to quantitative methods replaced the business statistics course. Supporters of this course reasoned that quantitative methods are useful for research, analysis, forecasting, and optimization. By "research," they pointed out, one should understand the gathering of information by means of samples, surveys, and experiments. By "analysis," the detection of trends, patterns, and relationships. And by "forecasting," the projection, extension or extrapolation of these trends, patterns, and relationships into new cases or times. These are objectives for which statistical

methods are designed. Supporters recognized, however, that no problem formulation in business is complete without a fourth dimension -- optimization, formally the province of management science or operations research, by which is understood the selection of the best of the available alternatives. Hardly any business problem exists, supporters argued, that does not involve to some extent research, analysis, forecasting, and optimization; not all these problems, of course, are amenable to quantitative methods, but enough important ones exist to justify a required course.

4 It appeared highly desirable for the replacement course to find cases illustrating business applications of methods for research, analysis, forecasting, and optimization, especially profit maximization. Although cases could be found involving research or analysis or forecasting or optimization, good cases touching all four dimensions in a unified whole were not readily available.

5 It appeared possible, however, to select elements from individual cases and weave them into an integrated problem having real components but not being real itself as a whole. For example, features could be drawn from one case having to do with sampling and from another related to analysis and forecasting to describe a fictional situation involving all three dimensions. Even so, a case, like any exercise or problem, is static: it describes, say, what was discovered after taking a sample of a given size by a particular method, what model was formulated based on this information, and what decisions were taken in the light of forecasts from this model; it does not lend itself to investigating what may have happened if different decisions were made in the light of different forecasts from a different model that appeared best in the light of different information based on a sample of a different size obtained by a different method. In addition, a case does not lend itself to variations; strict adherence to the original reduces its usefulness as an educational tool over time as its lessons become known to and are copied by an increasing number of students.

6 The last two shortcomings of a case are the advantages of a simulation, in which a situation is created by a computer program in a manner that depends on the student's choices. For example, a population can be described by computer statements, and a simple, stratified, or other sample of a given size created on request; or, a process generating a time series can be similarly described and a series of suitable length generated when needed. Minor or major variations of such a population or process can be easily implemented by modifying the statements, so as to give the simulation the flexibility needed for survival on repeated use in the hands of different instructors and students. An earlier example of this approach can be found in Cheng et al. (1992).

7 In the remainder of this paper, I describe briefly three such simulations that have been used with some success in classes of MBA students. They may also be used in business statistics courses at the upper undergraduate level, other business courses with a substantial statistical component (e.g., in marketing research or management science), or in statistics courses having an applications orientation. The full text of these simulations can be inspected at the web addresses given below. The files of these documents, the computer programs, teaching and technical notes, and sample student responses are freely available to instructors. Instructions for obtaining this information are given at the end of this paper.

2. Norgas Distributing Company

8 Norgas is described as the exclusive supplier of natural gas to a large metropolitan area in the Great Lakes region. At present, Norgas does not store gas and draws its daily supply directly from the main gas pipeline. An opportunity arises to lease recently developed storage facilities located near the pipeline and the market. Like other inventory, gas storage has the potential of reducing costs, allowing fluctuations in daily demand to be smoothed by buying more than is needed when the weather is warm and storing the excess supply for use when the weather is cold. The simulation was motivated by the operations of an existing gas utility. An earlier version appears in Tryfos (1998).

9 The objective of the simulation is to maximize next year's profit. Up to ten years of data are available at a certain cost; the data show the daily gas consumption, actual temperature and wind speed, and one-day-ahead forecasts of these variables by two weather forecasting services. Students must first decide how many years of

data to purchase. After the data are analyzed, decisions must also be made concerning the weather service to subscribe to, the model to forecast next day's gas demand, whether or not storage facilities will be leased, the minimum annual quantity of gas to be purchased, and the maximum quantity of gas to be withdrawn on any day from the pipeline; if storage is leased, a commitment must also be made regarding the maximum quantities of gas to be stored and transported on any day in the storage pipeline.

10 From the standpoint of statistical methods, the simulation touches on data analysis, regression, and time series analysis. A special computer program generates daily actual and forecast weather characteristics and gas consumption for the number of years requested.

3. Tenderdent Toothpaste

11 The text of the simulation describes a situation faced by the chief executive officer (CEO) of a pharmaceutical company manufacturing a toothpaste for sensitive teeth. The CEO has persuaded the company's board of directors of the need to review the current promotional policy, which treats Tenderdent as a drug and is aimed at dentists and physicians. The CEO proposes instead that the focus of advertising be the consumer and that Tenderdent be treated for promotional purposes like any other toothpaste. The board is not convinced that a different advertising message will be effective or that the market for this type of toothpaste is large enough for advertising to be profitable but agrees with the CEO's plan to "proceed with caution" in three stages. In the first stage, a survey of adults in a large metropolitan area will be commissioned to estimate the potential market for Tenderdent and the characteristics of potential buyers. If the results of the survey are encouraging then, in the second stage, Tenderdent will be test marketed in selected regions of the country. If the results of this test marketing in turn are encouraging, then in the third stage Tenderdent will be marketed in some or all of the regions in the country.

12 The simulation was motivated by the experience of a successful company manufacturing a toothpaste for sensitive teeth; an earlier and simpler version can be found in Tryfos (1996).

13 In the first stage, decisions are required concerning the sampling method to be used (simple, stratified, or two-stage sample of households) and the sample size. The second stage is an experiment, and decisions are needed regarding which regional markets to select on the basis of characteristics of these markets. Finally, the third stage decisions suggest the estimation of a model relating advertising to sales based on the information gathered in the second stage, and the determination of the optimal level of advertising and production in each regional market. As often happens in real life, the decisions at each stage represent commitments, and once made cannot be changed. The objective is the maximization of the profit from the entire venture.

14 From the standpoint of methods, the simulation involves sampling, data analysis, experimental design, and regression. As in the other two simulations, optimization requires no more sophistication than enumeration and intelligent search. Three special computer programs accept the student's decisions at each stage, generate the appropriate data in response to these decisions, and calculate the overall profit stemming from the entire sequence of decisions.

4. Superior Insurance Inc.

15 A new system for a standardized third-party automobile liability insurance is legislated to come into effect at the start of next year. Under the new system, the focus of insurance is the driver rather than the vehicle as with the existing system. Superior Insurance is one of several companies competing in the region, and the task facing the student is to formulate Superior's new premium policy so as to maximize profits in the coming year.

16 In essence, this means determining a "formula" by which the annual premium of a driver with given characteristics (such as gender, age, experience, and vehicle size) will be calculated. Drivers are expected to request such premium quotations from all firms competing in the region, and to purchase insurance from the

lowest bidder. In anticipation of the new legislation, an industry organization coordinated the construction of a database showing for each licensed driver in a given year in the past the total amount of claims made as well as driver and vehicle characteristics. Students must decide how many records to purchase from this database in the form of a simple random sample. A special computer program delivers this information, which must then be analyzed to determine the premium policy.

17 A second computer program treats each student as a competing company, accepts the premium formula from each such company, and simulates next year's operations. This is done by generating drivers and their characteristics, calculating the premium bid of each company, determining which company wins and sells the insurance policy, generating the amount of claim for each driver, and summing up to calculate the total revenue, total cost, and total profit for each competing company.

18 From the standpoint of methods, the simulation involves sampling, data analysis, regression and other methods for predicting categories of attributes.

5. Common Technical Features

19 All three simulations can be described as large-scale, non-trivial problems involving large sets of data. The data generated by the special programs are in the form of ASCII (text) files that can be read and analyzed with the help of spreadsheet (e.g., Microsoft Excel) or statistical programs (e.g., Minitab, SAS, or SPSS). The special programs are modest, "no-frills" DOS programs written in C. Simple adjustments can be made requiring no knowledge of C programming or recompilation, so that the generated data can be made to vary from one use to another; other adjustments can be made by modifying the source code and recompiling the programs. The Norgas and Tenderdent programs as well as the first Superior program can be executed in the form provided; however, the second Superior program simulating the market performance requires some knowledge of C and a C or C++ compiler.

20 With due respect to students' zeal for finding "solutions" with minimum effort, achieved by copying others' work or attempting to discover loopholes in the programs (to which zeal I can attest from experience), an effort was made to make the programs reasonably secure. A password, controlled by the instructor, is needed to run each public program once only; also, provision is made for program files to be stored in protected server directories. To avoid having to store large quantities of data, the programs generate data as they execute. However, an instructor is able to replicate at any time any set of previously generated data if such replication is necessary to confirm or otherwise check student work.

21 Instructions on all these technical features are provided in the Technical and Teaching Notes accompanying each simulation.

6. Pedagogical Features

22 A clear message is given that useful information is rarely free, and that the cost of additional information must somehow be related to the expected benefits.

23 Each simulation has a single objective -- the maximization of profit under conditions of uncertainty. Students are not directed to apply particular methods or to make particular assumptions. Nevertheless, they appear to realize that in pursuing this purely business objective statistical methods are eminently reasonable and appropriate.

24 Each simulation involves four stages corresponding to research, analysis, forecasting, and optimization, designed to be carried out over a period of time. At each stage, students can be invited to reflect on how the task may be carried out. There can follow a class discussion and lecture, after which students must make decisions

and commitments. In a final report and presentation students can explain the alternatives considered at each stage, their rationale for the decisions taken, and their expectations for the final outcome.

25 Students can be evaluated in part by the profit they attain in relation to that of other students -- what that part should be can be left to the instructor's discretion. Some recognition of attained profit is necessary to motivate students and provide an incentive for accurate work, but this need not be reflected in the student's grade. It could be made clear that, very much as in the real world, results depend not only on actions under one's control, but also on events beyond it -- such as an unlikely but nevertheless observed "non-representative" sample, or a competitor's uncooperative behavior. In my experience, business students have no difficulty accepting this view of the world. Indeed, I find that they welcome the challenge that competition provides and, especially if they work in teams, the opportunity to do better than their peers.

26 Precisely this approach has been used in the required MBA course at York University referred to earlier. The entire course, a seven-week introduction to quantitative methods, is centered on one of the simulations. The 40 to 50 students in each section form teams of their choice consisting of one to four members; the final report is due and a presentation is made on the last day of classes, on the very same day that the simulation results are announced. Each team's mark depends in large part on the quality of the paper and presentation and in small part on the profit achieved in relation to that of other teams. The individual student's final grade depends also on the quality of his or her participation in class discussions.

27 The simulations are used differently in an elective, fourth-year undergraduate or second-year graduate, one-semester econometrics course for business students. Here, one of the three simulations serves as a capstone case at the end of a sequence of six to eight smaller and less demanding cases, each of which is assigned to and presented by different students. The student's final grade depends approximately equally on the cases, the selected simulation, and a final examination.

28 A final pedagogical feature is aimed at the instructor, particularly one with background in methods only. If indeed these simulations are convincing classroom descriptions of business problems, an instructor who places himself or herself in the position of the decision maker may wish to reflect on just which statistical methods among the many available are the most useful in addressing business problems.

7. For Additional Information

29 The full text of the three simulations can be viewed at the following addresses:

Norgas Distributing Company

Tenderdent Toothpaste

Superior Insurance Inc.

The appearance of these texts in the browser is not, of course, as good as in print. The text files (in Microsoft Word format, from which the text can be printed), the executable programs and required data files, as well as the source code of the special programs in C, technical and teaching notes, and sample student responses can be downloaded by following the instructions in

cdwnld.cfm

Instructors are free to use as is or modify all this material for classroom purposes provided the original source is acknowledged. Comments on the simulations and any suggestions for their improvement will be greatly appreciated.

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