STATISTICS

FOR BUSINESS AND ECONOMICS

FOURTH EDITION

JAMES T. McCLAVE
P. GEORGE BENSON

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STATISTICS FOR BUSINESS AND ECONOMICS

JAMES T. McCLAVE
College of Business Administration
University of Florida

P. GEORGE BENSON
Curtis L. Carlson School of Management
University of Minnesota

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PREFACE

The fourth edition of *Statistics for Business and Economics* finds the application of statistics to business and economic problems in the midst of a number of significant changes. The availability of microcomputers with a wide range of statistical software has dramatically affected the amount of time we spend teaching computational formulas. The use of statistical quality control in American industry is perhaps the fastest-growing application of statistics in any area. The same corporate structure which nearly 40 years ago forced W. Edwards Deming to take his revolutionary ideas to Japan has welcomed him back as a conquering hero. Deming and his disciples are in constant demand in both academic and corporate circles, and the impact of their philosophy on the statistical education of business students is and will be profound. Academic professional organizations are paying increased attention to the content of business statistics courses and to the philosophy and manner in which they are taught.

In light of these and other developments, we have decided that the time has come to acknowledge that the text we wrote 10 years ago is not the same one we would write today. For example, 10 years ago the calculator had taken the "arithmetic" out of analysis of variance, but not the formulas. The computer gives us an additional option: We can use precious time teaching the interpretation of ANOVA results rather than cookbook formulas that produce those results. This fourth edition exercises that option (and many others like it).

Before detailing the specifics of the fourth edition, we stress that the underlying philosophy of the text is unchanged, despite the many new features and additional options. Our original intent was to write a text *for the students* that stressed *inference making*. If anything, the rapid evolution of "business statistics" is making that easier to accomplish.

1. **Using the Computer.** A new feature has been added at the end of most chapters to encourage the use of computers in the analysis of real data. A demographic data base, consisting of 1,000 observations on 15 variables, has been described in Appendix C and is available on diskette from the publisher. Each "Using the Computer" section provides one or more computer exercises that utilize the data in Appendix C and enhance the new material covered in the chapter.
2. **Quality Control.** Numerous case studies, examples, and exercises that focus on statistical quality control applications have been added throughout the text. Since the application of statistical ideas to quality management and quality control has become so pervasive, we decided that the subject needed to be stressed throughout the text, as the relevant statistical concepts are covered, rather than concentrated in a few pages or chapter devoted to the subject.

   Examples include a quality control perspective on the explosion of the space shuttle *Challenger* (Case Study 5.3); quality control problems associated with mass production (Example 6.13); quality comparisons of rental cars (Case Study 7.1); introduction to quality control charts (Case Studies 8.3 and 8.4); quality control problems in the telecommunications industry following deregulation

(Example 8.12); comparison of manual and automated quality inspection procedures (Exercise 9.41); analysis of the American Society for Quality Control survey of upper-level executives (Exercise 9.101); and the use of regression analysis in the quality control process (Exercise 10.21)

3. **Exploratory Data Analysis.** The computer permits the analyst to look at the data from every angle in order to extract all the information they have to offer. The use of microcomputer packages to generate stem and leaf displays, box plots, and the more traditional histograms is introduced in Chapters 2 and 3, and utilized throughout the text. We are careful to delineate the difference between descriptive and inferential statistics, and the student is constantly reminded of the necessity to consider the reliability of any statistical procedure used.
4. **Computers in Regression and Residual Analysis.** Ten years ago we set out to include the most complete treatment of regression analysis on the market, because we believed that modeling and forecasting were two of the most important applications of statistics in business. Our view has not changed, and the computer has enabled aspects of modeling to be realized that were only theoretical constructs when we wrote the original text. In keeping with our goal of a thorough, modern treatment of regression analysis, the fourth edition introduces computer printouts in the simple linear regression chapter, adds significantly to the number of examples and exercises that use the computer for regression analyses, and incorporates residual analyses into the model-building process. Although our first three editions made substantial use of the computer in the treatment of regression modeling, this edition adds significantly to that base. Microcomputer printouts are included, more exercises show printouts instead of requiring the student to perform the calculations, and more exercises with real data requiring the student to use the computer have been added. In addition, both Chapters 11 and 12 contain new sections showing how to use the computer to perform residual analyses, and, more importantly, how to integrate them into the model-building process. The residual analyses lead naturally to a more complete discussion of transformations, including significantly more space devoted to the important multiplicative model.
5. **Tests of Hypotheses.** Much current debate centers on how and what, if anything, to teach about testing hypotheses. Our view is that a modern text must present the subject, because much research and application in business and economics continues to make use of statistical testing procedures. In this fourth edition, we have expanded the explanatory material about testing, including a new (optional) section on the computation of Type II error probabilities (β) and on the power of tests. We have also added exercises that require the student to confront the issue of which inferential procedure—testing or confidence intervals—provides more information about a parameter. Thus, the fourth edition offers an option as to the depth of treatment the instructor selects for testing hypotheses, while at the same time encouraging the student to contrast and to evaluate the statistical procedures employed.
6. **Normal Distribution and Sampling Distributions.** The normal distribution remains the cornerstone of applied statistics. Although robustness rightfully receives increased attention, the Central Limit Theorem ensures the continued

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importance of the normal distribution. We have added more explanatory examples on the use of the normal distribution in Chapter 6, and we have replaced the more difficult two-sample material in the sampling distribution chapter (Chapter 7) with an expanded treatment of the one-sample case, including more computer simulations of sampling distributions and an introduction to the sampling distribution of the sample proportion for a binomial random variable.

7. **Analysis of Variance.** The fourth edition adopts a computerized rather than a "cookbook" approach to ANOVA. All calculation formulas are relegated to Appendix D, and the emphasis is changed to the understanding and interpretation of designed experiments. The terminology of designed experiments is defined and utilized throughout the chapter, with constant reinforcement by example. Computer printouts are presented for each type of analysis covered, with space that was formerly occupied by tedious calculations now devoted to interpretation of the statistical results produced by the software. The Bonferroni multiple comparisons procedure is introduced early and is utilized during each analysis, where it would naturally occur, rather than in a separate section at the end of the chapter. Since virtually every ANOVA model can be written as a regression model (certainly every one in this text, with a single random component), we develop the relationship between regression and ANOVA models in an optional section.
8. **Determination of Sample Size.** Part of the quality control aspect of the statistical revolution in business applications is increased attention to sampling efforts necessary to achieve specified statistical objectives. In accordance with this, we have included separate sections for determining the sample size for estimating a population mean and a binomial probability. Sample size formulas in terms of both the bound on the error of estimation and the total width of the confidence interval are provided.
9. **Normal Approximation to Binomial Probabilities.** The rationale behind and the conditions under which the normal distribution can be used for approximating binomial probabilities are significantly expanded in Chapter 6.
10. **Real Applications of Statistics in Business and Economics.** From the start we have attempted to include many examples and exercises that draw on the extensive (and growing) literature containing real applications of statistics in business and economics. The fourth edition adds to and updates the many examples, exercises, and case studies that represent applications of statistics to real business problems. It should be noted, however, that constructed exercises and examples often better serve our pedagogic objectives, and we therefore continue to make use of them where appropriate.

In spite of the fact that we consider the fourth edition a major revision, the flexibility of past editions is maintained. Sections that are not prerequisite to succeeding sections and chapters are marked "(Optional)." For example, an instructor who wishes to devote significant time to exploratory data analysis might cover all topics in Chapters 2 and 3. In contrast, an instructor who wishes to move rapidly into inferential procedures might omit optional sections, devoting only several lectures to these chapters.

We have maintained the features of this text that we believe make it unique among introductory statistics texts for business courses. These features, which assist the student in achieving an overview of statistics and an understanding of its relevance in the solution of business problems, are as follows:

1. **Case Studies.** (See the list of case studies on page xxi.) Many important concepts are emphasized by the inclusion of case studies, which consist of brief summaries of actual business applications of the concepts and are often drawn directly from the business literature. These case studies allow the student to see business applications of important statistical concepts immediately after the introduction of the concepts. The case studies also help to answer by example the often asked questions, "Why should I study statistics? Of what relevance is statistics to business?" Finally, the case studies constantly remind the student that each concept is related to the dominant theme—statistical inference.
2. **Where We've Been . . . Where We're Going . . .** The first page of each chapter is a "unification" page. Our purpose is to allow the student to see how the chapter fits into the scheme of statistical inference. First, we briefly show how the material presented in previous chapters helps us to achieve our goal (Where We've Been). Then, we indicate what the next chapter (or chapters) contributes to the overall objective (Where We're Going). This feature allows us to point out that we are constructing the foundation block by block, with each chapter an important component in the structure of statistical inference. Furthermore, this feature provides a series of brief résumés of the material covered as well as glimpses of future topics.
3. **Many Examples and Exercises.** We believe that most students learn by doing. The text contains many worked examples to demonstrate how to solve various types of problems. We then provide the student with a large number (more than 1,300) of exercises. The answers for most are included at the end of the text. The exercises are of two types:
   a. **Learning the Mechanics.** These exercises are intended to be straightforward applications of the new concepts. They are introduced in a few words and are unhampered by a barrage of background information designed to make them "practical," but which often detracts from instructional objectives. Thus, with a minimum of labor, the student can recheck his or her ability to comprehend a concept or a definition.
   b. **Applying the Concepts.** The mechanical exercises described above are followed by realistic exercises that allow the student to see applications of statistics to the solution of problems encountered in business and economics. Once the mechanics are mastered, these exercises develop the student's skills at comprehending realistic problems that describe situations to which the techniques may be applied.
4. **On Your Own . . .** The chapters end with an exercise entitled "On Your Own . . . ." The intent of this exercise is to give the student some hands-on experience with a business application of the statistical concepts introduced in the chapter. In most cases, the student is required to collect, analyze, and interpret data relating to some business phenomenon.

5. A Simple, Clear Style. We have tried to achieve a simple and clear writing style. Subjects that are tangential to our objective have been avoided, even though some may be of academic interest to those well-versed in statistics. We have not taken an encyclopedic approach in the presentation of material.
6. An Extensive Coverage of Multiple Regression Analysis and Model Building. This topic represents one of the most useful statistical tools for the solution of business problems. Although an entire text could be devoted to regression modeling, we feel that we have presented a coverage that is understandable, usable, and much more comprehensive than the presentations in other introductory business statistics texts. We devote three chapters to discussing the major types of inferences that can be derived from a regression analysis, showing how these results appear in computer printouts and, most important, selecting multiple regression models to be used in an analysis. Thus, the instructor has the choice of a one-chapter coverage of simple regression, a two-chapter treatment of simple and multiple regression, or a complete three-chapter coverage of simple regression, multiple regression, and model building. The following two chapters on index numbers and time series analysis are closely tied to the three chapters on multiple regression analysis because they present an introduction to forecasting based on time-dependent data. This extensive coverage of such useful statistical tools will provide added evidence to the student of the relevance of statistics to the solution of business problems.
7. Footnotes and Appendix A. Although the text is designed for students with a noncalculus background, footnotes explain the role of calculus in various derivations. Footnotes are also used to inform the student about some of the theory underlying certain results. Appendix A presents some useful counting rules for the instructor who wishes to place greater emphasis on probability. Consequently, we think the footnotes and Appendix A provide an opportunity for flexibility in the mathematical and theoretical level at which the material is presented.
8. Decision Analysis. We have included a two-chapter treatment of decision analysis. In Chapter 18 the classic decision problem is presented. In addition to the standard expected payoff criterion using prior information, several other decision-making criteria are presented. This includes a rather complete introduction to the role of utility functions in decision analysis. In Chapter 19 Bayes' Rule is used both to compute the expected value of sample information before it is purchased and to revise the prior probabilities after sample information is obtained. Throughout both chapters we stress (by setting off in boxes) a step-by-step approach for all calculations. This allows the student to devote time to understanding the concepts and philosophies of decison analysis and to avoid being caught up in the necessary tedious calculations that accompany these analyses.
9. Supplementary Material. A solutions manual, a study guide, a Minitab supplement, an integrated companion software system, a computer-generated test system, and a 1,000-observation demographic data base are available.
   a. Solutions Manual (by Nancy Shafer). The solutions manual presents the solutions to most odd-numbered exercises in the text. Many points are clarified and expanded to provide maximum insight into and benefit from each exercise.

b. Study Guide (by Susan L. Reiland). For each chapter, the study guide includes (1) a brief summary that highlights the concepts and terms introduced in the textbook; (2) section-by-section examples with detailed solutions; and (3) exercises (with answers provided at the end of the study guide) that allow the student to check mastery of the material in each section.

c. Minitab Supplement (by David D. Krueger and Ruth K. Meyer). The Minitab computer supplement was developed to be used with Minitab Release 5.1, a general-purpose statistical computing system. The supplement, which was written especially for the student with no previous experience with computers, provides step-by-step descriptions of how to use Minitab effectively as an aid in data analysis. Each chapter begins with a list of new commands introduced in the chapter. Brief examples are then given to explain new commands, followed by examples from the text illustrating the new and previously learned commands. Where appropriate, simulation examples are included. Exercises, many of which are drawn from the text, conclude each chapter.

   A special feature of the supplement is a chapter describing a survey sampling project. The objectives of the project are to illustrate the evaluation of a questionnaire, provide a review of statistical techniques, and illustrate the use of Minitab for questionnaire evaluation.

d. DellenStat (by Michael Conlon). DellenStat is an integrated statistics package consisting of a workbook and an IBM PC floppy diskette with software and example sets of data. The system contains a file creation and management facility, a statistics facility, and a presentation facility. The software is menu-driven and has an extensive help facility. It is completely compatible with the text.

   The DellenStat workbook describes the operation of the software and uses examples from the text. After an introductory chapter for new computer users, the remaining chapters follow the outline of the text. Additional chapters show how to create new sets of data. Technical appendices cover material for advanced users and programmers.

   DellenStat runs on any IBM PC or close compatible with at least 256K of memory and at least one floppy disk drive.

e. DellenTest. This unique computer-generated random test system is available to instructors without cost. Utilizing an IBM PC computer and a number of commonly used dot-matrix printers, the system will generate an almost unlimited number of quizzes, chapter tests, final examinations, and drill exercises. At the same time, the system produces an answer key and student worksheet with an answer column that exactly matches the column on the answer key.

f. Data Base. A demographic data set was assembled based on a systematic random sample of 1,000 U.S. zip codes. Demographic data for each zip code area selected were supplied by CACI, an international demographic and market information firm. Fifteen demographic measurements (including population, number of households, median age, median household income, variables related to the cost of housing, educational levels, the work force,

and purchasing potential indexes based on the Bureau of the Census Consumer Expenditure Surveys) are presented for each zip code area.

Some of the data are referenced in the "Using the Computer" sections. The objectives are to enable the student to analyze real data in a relatively large sample using the computer, and to gain experience using the statistical techniques and concepts on real data.

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Gordon J. Alexander
University of Minnesota

Larry M. Austin
Texas Tech University

Clarence Bayne
Concordia University

Carl Bedell
Philadelphia College of Textiles and Science

David M. Bergman
University of Minnesota

William H. Beyer
University of Akron

Atul Bhatia
University of Minnesota

Jim Branscome
University of Texas at Arlington

Francis J. Brewerton
Middle Tennessee State University

Daniel Brick
College of St. Thomas

Robert W. Brobst
University of Texas at Arlington

Michael S. Broida
Miami University of Ohio

Edward Carlstein
University of North Carolina at Chapel Hill

John M. Charnes
University of Minnesota

Chih-Hsu Cheng
University of Minnesota

Larry Claypool
Oklahoma State University

Edward R. Clayton
Virginia Polytechnic Institute and State University

Ronald L. Coccari
Cleveland State University

Ken Constantine
University of New Hampshire

Jim Daly
California State Polytechnic Institute

Dileep Dhavale
University of Northern Iowa

Carol Eger
Stanford University

Robert Elrod
Georgia State University

Douglas A. Elvers
University of North Carolina at Chapel Hill

Susan Flach
General Mills, Inc.

Alan E. Gelfand
University of Connecticut

Joseph Glaz
University of Connecticut at Storrs

Michael E. Hanna
University of Texas at Arlington

Don Holbert
Oklahoma State University

James Holstein
University of Missouri

Warren M. Holt
Southeastern Massachusetts University

Steve Hora
Texas Tech University

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Iris B. Ibrahim
Clemson University

Marius Janson
University of Missouri

Ross H. Johnson
Madison College

Timothy J. Killeen
University of Connecticut

David D. Krueger
St. Cloud State University

Richard W. Kulp
Wright-Patterson AFB, Air Force Institute of Technology

Martin Labbe
State University of New York College at New Paltz

James Lackritz
California State University at San Diego

Philip Levine
William Patterson College

Eddie M. Lewis
University of Southern Mississippi

Pi-Erh Lin
Florida State University

Ruth K. Meyer
St. Cloud State University

Paul I. Nelson
Kansas State University

Paula M. Oas
General Furniture Leasing

William M. Partian
Fordham College

Vijay Pisharody
University of Minnesota

P. V. Rao
University of Florida

Jan Saraph
University of Minnesota

Craig W. Slinkman
University of Texas at Arlington

Donald N. Steinnes
University of Minnesota at Duluth

Virgil F. Stone
Texas A and I University

Chipei Tseng
Northern Illinois University

Pankaj Vaish
Arthur Andersen & Company

Charles F. Warnock
Colorado State University

William J. Weida
United States Air Force Academy

T. J. Wharton
University of New Hampshire

Kathleen M. Whitcomb
University of Minnesota

Edna White
Texas A & M University

Steve Wickstrom
University of Minnesota

James Willis
Louisiana State University

Douglas A. Wolfe
Ohio State University

Dilek Yeldan
University of Minnesota

Fike Zahroon
Moorhead State University

CONTENTS

CHAPTER 1

WHAT IS STATISTICS? 1

1.1 Statistics: What Is It? 2
1.2 The Elements of Statistics 5
1.3 Statistics: Witchcraft or Science? 7
1.4 The Role of Statistics in Managerial Decision-Making 9

CHAPTER 2

GRAPHICAL DESCRIPTIONS OF DATA 15

2.1 Types of Business Data 16
2.2 Graphical Methods for Describing Qualitative Data: The Bar Chart (Optional) 18
2.3 Graphical Methods for Describing Qualitative Data: The Pie Chart (Optional) 26
2.4 Graphical Methods for Describing Quantitative Data: Stem and Leaf Displays 34
2.5 Graphical Methods for Describing Quantitative Data: Histograms 43
2.6 Cumulative Relative Frequency Distributions (Optional) 55
2.7 Distorting the Truth with Pictures (Optional) 60

CHAPTER 3

NUMERICAL DESCRIPTIVE MEASURES 75

3.1 The Mode: A Measure of Central Tendency 76
3.2 The Arithmetic Mean: A Measure of Central Tendency 77
3.3 The Median: Another Measure of Central Tendency 82
3.4 The Range: A Measure of Variability 92
3.5 Variance and Standard Deviation 94
3.6 Calculation Formulas for Variance and Standard Deviation 97
3.7 Interpreting the Standard Deviation 104
3.8 Calculating a Mean and Standard Deviation from Grouped Data (Optional) 115
3.9 Measures of Relative Standing 117
3.10 Box Plots: Graphical Descriptions Based on Quartiles (Optional) 124

CHAPTER 4

PROBABILITY 145

4.1 Events, Sample Spaces, and Probability 146
4.2 Compound Events 160
4.3 Complementary Events 163
4.4 Conditional Probability 169
4.5 Probabilities of Unions and Intersections 174
4.6 Random Sampling 184

CHAPTER 5 DISCRETE RANDOM VARIABLES 201

5.1 Two Types of Random Variables 202
5.2 Probability Distributions for Discrete Random Variables 204
5.3 Expected Values of Discrete Random Variables 209
5.4 The Binomial Random Variable 220
5.5 The Poisson Random Variable (Optional) 235
5.6 The Hypergeometric Random Variable (Optional) 242
5.7 The Geometric Random Variable (Optional) 246

CHAPTER 6 CONTINUOUS RANDOM VARIABLES 259

6.1 Continuous Probability Distributions 260
6.2 The Uniform Distribution 261
6.3 The Normal Distribution 266
6.4 The Exponential Distribution (Optional) 282
6.5 Approximating a Binomial Distribution with a Normal Distribution 291

CHAPTER 7 SAMPLING DISTRIBUTIONS 307

7.1 Introduction to Sampling Distributions 309
7.2 Properties of Sampling Distributions: Unbiasedness and Minimum Variance 314
7.3 The Sampling Distribution of the Sample Mean 317
7.4 The Relationship Between Sample Size and a Sampling Distribution 326

CHAPTER 8 ESTIMATION AND A TEST OF HYPOTHESIS: SINGLE SAMPLE 341

8.1 Large-Sample Estimation of a Population Mean 342
8.2 Determining the Sample Size Necessary for Making Inferences About a Population Mean 351
8.3 Large-Sample Test of Hypothesis About a Population Mean 356
8.4 Calculating Type II Error Probabilities: More About β (Optional) 372
8.5 Observed Significance Levels; p-Values 382
8.6 Small-Sample Inferences About a Population Mean 386
8.7 Large-Sample Inferences About a Binomial Probability 398
8.8 Determining the Sample Size Necessary to Make Inferences About a Binomial Probability 407

CHAPTER 9 TWO SAMPLES: ESTIMATION AND TESTS OF HYPOTHESES 419

9.1 Large-Sample Inferences About the Difference Between Two Population Means: Independent Sampling 420
9.2 Small-Sample Inferences About the Difference Between Two Population Means: Independent Sampling 431
9.3 Comparing Two Population Variances: Independent Random Samples 441
9.4 Inferences About the Difference Between Two Population Means: Paired Difference Experiments 450
9.5 Inferences About the Difference Between Two Population Proportions: Independent Binomial Experiments 463
9.6 Determining the Sample Size 473

CHAPTER 10
SIMPLE LINEAR REGRESSION 487

10.1 Probabilistic Models 488
10.2 Fitting the Model: The Method of Least Squares 491
10.3 Model Assumptions 500
10.4 An Estimator of σ^2 502
10.5 Assessing the Usefulness of the Model: Making Inferences About the Slope β_1 506
10.6 Correlation: Another Measure of the Usefulness of the Model 514
10.7 The Coefficient of Determination 517
10.8 Using the Model for Estimation and Prediction 525
10.9 Simple Linear Regression: An Example 534
10.10 Using the Computer for Simple Linear Regression 538

CHAPTER 11
MULTIPLE REGRESSION 555

11.1 A Multiple Regression Analysis: The Model and the Procedure 556
11.2 Model Assumptions 557
11.3 Fitting the Model: The Method of Least Squares 558
11.4 Estimation of σ^2, the Variance of ε 561
11.5 Estimating and Testing Hypotheses About the β Parameters 562
11.6 Checking the Usefulness of a Model: R^2 and the Analysis of Variance F Test 575
11.7 Using the Model for Estimation and Prediction 590
11.8 Multiple Regression: An Example 593
11.9 Statistical Computer Programs 596
11.10 Residual Analysis: Checking the Regression Assumptions 601
11.11 Some Pitfalls: Estimability, Multicollinearity, and Extrapolation 622

CHAPTER 12
INTRODUCTION TO MODEL BUILDING 647

12.1 The Two Types of Independent Variables: Quantitative and Qualitative 649
12.2 Models with a Single Quantitative Independent Variable 651
12.3 Models with Two Quantitative Independent Variables 661
12.4 Model Building: Testing Portions of a Model 669
12.5 Models with One Qualitative Independent Variable 682
12.6 Comparing the Slopes of Two or More Lines 693
12.7 Comparing Two or More Response Curves 707
12.8 Model Building: Stepwise Regression 721
12.9 Model Building: Residual Analysis and Transformations 728

CHAPTER 13
TIME SERIES: INDEX NUMBERS AND DESCRIPTIVE ANALYSES 755

13.1 Index Numbers: An Introduction 756
13.2 Simple Index Numbers 757
13.3 Composite Index Numbers 762
13.4 Smoothing with Moving Averages 774
13.5 Exponential Smoothing 782

CHAPTER 14

TIME SERIES: MODELS AND FORECASTING 795

14.1 Time Series Components 796
14.2 Forecasting: Exponential Smoothing 798
14.3 Forecasting Trends: The Holt–Winters Forecasting Model 801
14.4 Forecasting Trends: Simple Linear Regression 811
14.5 Seasonal Regression Models 815
14.6 Autocorrelation and the Durbin–Watson Test 824
14.7 Forecasting with Autoregressive Models 831

CHAPTER 15

ANALYSIS OF VARIANCE 849

15.1 Elements of a Designed Experiment 850
15.2 The Completely Randomized Design 856
15.3 The Randomized Block Design 878
15.4 Factorial Experiments 897
15.5 Using Regression Analysis for ANOVA (Optional) 916

CHAPTER 16

NONPARAMETRIC STATISTICS 945

16.1 Comparing Two Populations: Wilcoxon Rank Sum Test for Independent Samples 947
16.2 Comparing Two Populations: Wilcoxon Signed Rank Test for the Paired Difference Experiment 956
16.3 Kruskal–Wallis H Test for a Completely Randomized Design 965
16.4 The Friedman F_r Test for a Randomized Block Design 973
16.5 Spearman's Rank Correlation Coefficient 979

CHAPTER 17

THE CHI-SQUARE TEST AND THE ANALYSIS OF CONTINGENCY TABLES 1003

17.1 One-Dimensional Count Data: Multinomial Distribution 1004
17.2 Contingency Tables 1013
17.3 Contingency Tables with Fixed Marginal Totals 1026
17.4 Caution 1027

CHAPTER 18

DECISION ANALYSIS USING PRIOR INFORMATION 1041

18.1 Three Types of Decision Problems 1043
18.2 Decision-Making Under Uncertainty: Basic Concepts 1045
18.3 Two Ways of Expressing Outcomes: Payoffs and Opportunity Losses 1049
18.4 Characterizing the Uncertainty in Decision Problems 1055
18.5 Solving the Decision Problem Using the Expected Payoff Criterion 1057
18.6 Two Nonprobabilistic Decision-Making Criteria: Maximax and Maximin (Optional) 1065
18.7 The Expected Utility Criterion 1068
18.8 Classifying Decision-Makers by Their Utility Functions 1073

CHAPTER 19

DECISION ANALYSIS USING PRIOR AND SAMPLE INFORMATION 1087

19.1 Revising State of Nature Probabilities: Baye's Rule 1088
19.2 Solving Decision Problems Using Posterior Probabilities 1095
19.3 The Expected Value of Perfect Information 1099
19.4 The Expected Value of Sample Information: Preposterior Analysis (Optional) 1106

19.5 An Example of a Two-Action, Infinite-State Decision Problem (Optional) 1121

CHAPTER 20
SURVEY SAMPLING 1131

20.1 Terminology 1134
20.2 Sample Survey Designs 1135
20.3 Estimation in Survey Sampling: Bounds on the Error of Estimation 1139
20.4 Estimation for Simple Random Sampling 1141
20.5 Simple Random Sampling: Nonresponse 1147
20.6 Stratified Random Sampling 1148
20.7 Cluster Sampling 1156
20.8 Determining the Sample Size 1164

APPENDIX A BASIC COUNTING RULES 1175

APPENDIX B TABLES 1179
Table I Random Numbers 1181
Table II Binomial Probabilities 1184
Table III Poisson Probabilities 1189
Table IV Normal Curve Areas 1194
Table V Exponentials 1195
Table VI Critical Values of t 1197
Table VII Percentage Points of the F Distribution, $\alpha = .10$ 1198
Table VIII Percentage Points of the F Distribution, $\alpha = .05$ 1200
Table IX Percentage Points of the F Distribution, $\alpha = .025$ 1202
Table X Percentage Points of the F Distribution, $\alpha = .01$ 1204
Table XI Critical Values of T_L and T_U for the Wilcoxon Rank Sum Test: Independent Samples 1206
Table XII Critical Values of T_0 in the Wilcoxon Paired Difference Signed Rank Test 1207
Table XIII Critical Values of χ^2 1208
Table XIV Critical Values for the Durbin–Watson d Statistic, $\alpha = .05$ 1210
Table XV Critical Values for the Durbin–Watson d Statistic, $\alpha = .01$ 1211
Table XVI Critical Values of Spearman's Rank Correlation Coefficient 1212

APPENDIX C DATA SET 1213

APPENDIX D CALCULATION FORMULAS FOR ANALYSIS OF VARIANCE 1217
Answers to Selected Exercises 1221
Index 1257

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