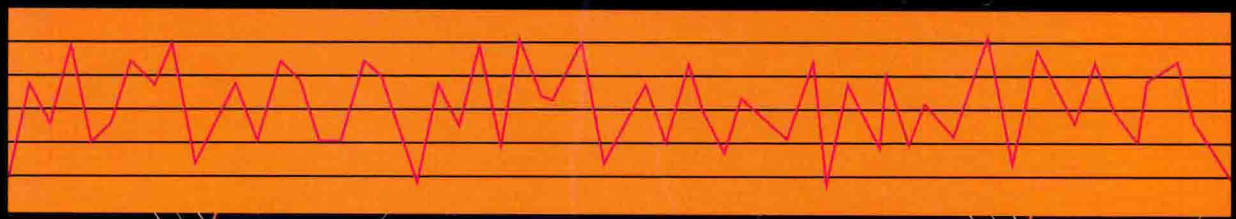
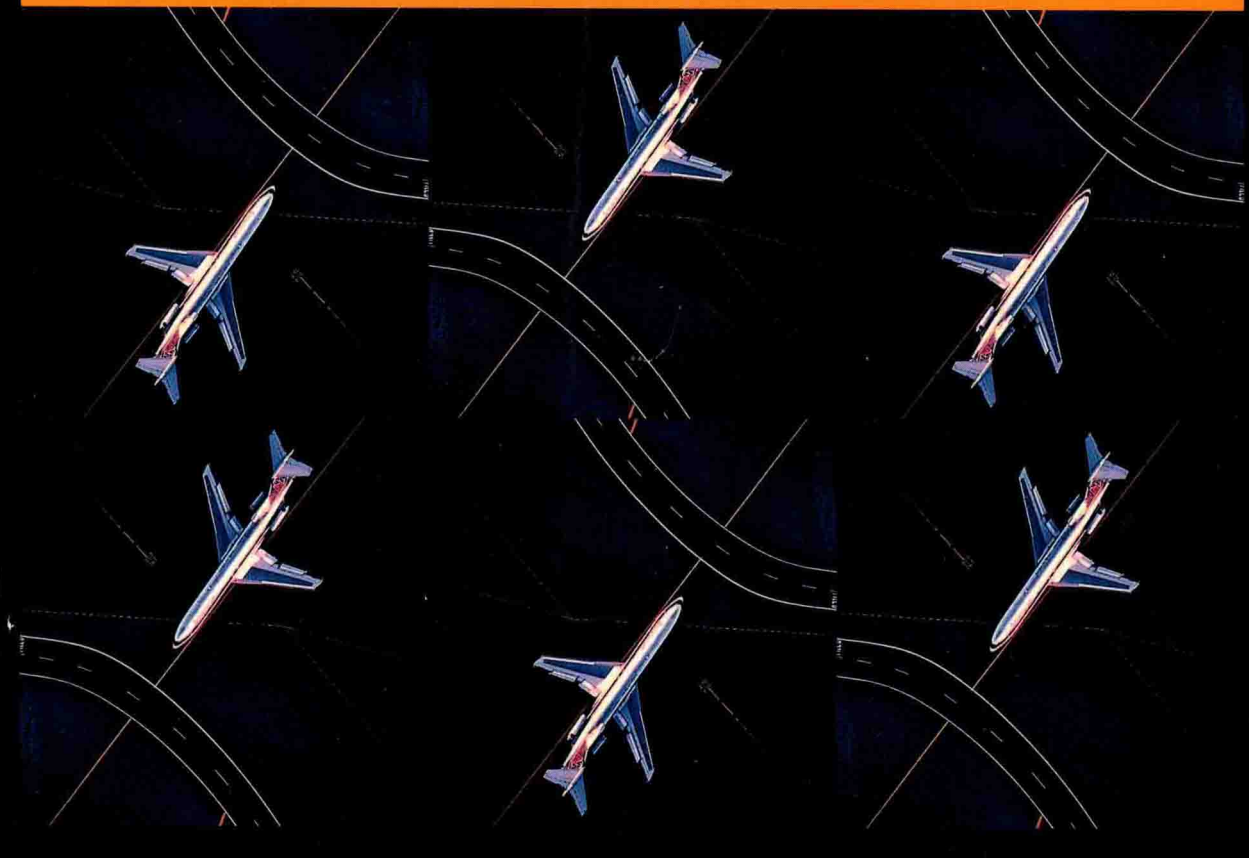
KELLER
WARRACK
BARTEL

STATISTICS

FOR MANAGEMENT AND ECONOMICS

ABBREVIATED EDITION





Statistics for Management and Economics

Gerald Keller
Wilfrid Laurier University

Brian Warrack
Wilfrid Laurier University

Henry Bartel
York University

Abbreviated Edition

Duxbury Press
An Imprint of Wadsworth Publishing Company
Belmont, California

DEDICATION

Gita, Barbara, Jeffery, and Jonathan
G.K.

Cynthia and Karen
B.W.

Margaret, Tanya, and Annatasha
H.B.

Assistant Editor: Julie Butler

Editorial Assistant: Jennifer Burger

Production Editor: Vicki Friedberg

Managing Designer: Carolyn Deacy

Print Buyer: Barbara Britton

Art Editor: Kelly Murphy

Permissions Editor: Jeanne Bosschart

Text and Cover Designer: Bruce Kortebein/
Design Office

Cover Photograph: © 1991 Jay Maisel

Copy Editor: Mary Roybal

Technical Illustrator: Teshin Associates

Printer: R. R. Donnelley & Sons, Crawfordsville, IN

Duxbury Press
An Imprint of Wadsworth Publishing Company
A division of Wadsworth, Inc.

Printed in the United States of America
2 3 4 5 6 7 8 9 10—98 97 96 95 94

Library of Congress Cataloging in Publication Data
Keller, Gerald.
Statistics for management and economics /
Gerald Keller, Brian Warrack, Henry Bartel.—
Abbreviated ed.
p. cm.
Includes index.
ISBN 0-534-17775-1
1. Management—Statistical methods.
2. Economics—Statistical methods. I. Warrack, Brian.
II. Bartel, Henry. III. Title.
HD30.215.K452 1994
658.4'033—dc20 92-34843

Techniques Illustrated by Computer Output

TECHNIQUE	MINITAB	SAS	EXAMPLE	PAGE
Histogram	✓	✓	—	23
Stem and leaf	✓	✓	—	30
Descriptive statistics	✓	✓	3.9	71, 72
Box plot	✓	✓	—	86, 87
z-estimator of μ	✓		7.1	249
z-test of μ	✓		7.2, 7.3	260, 264
z-test of μ: p-value	✓		7.4	271
t-test of μ	✓	✓	8.1	297
t-estimator of μ	✓	✓	8.2, 10.1 (c)	299, 300, 416
z-test of $\mu_1 - \mu_2$	✓	✓	9.3, 10.1 (a), 17.1 (c)	340, 341, 413, 819
t-test of $\mu_1 - \mu_2$	✓	✓	9.5	345
t-test of μ_D	✓	✓	9.7	358
z-test of $p_1 - p_2$ (counts)	✓	✓	10.1 (b)	414, 415
ANOVA (completely randomized design)	✓	✓	11.1, 11.2, 17.2 (a)	442, 443, 445, 822
ANOVA (randomized block design)	✓	✓	11.4, 11.5	458, 460, 462
Tuckey's multiple comparison method		✓	11.6	473
χ^2-test of a contingency table	✓	✓	12.2	510, 511
Wilcoxon rank sum test for independent samples	✓	✓	13.2, 13.3, 17.1 (a, b)	553, 554, 556, 557, 818
Sign test	✓		13.5	565
Wilcoxon signed rank sum test for matched pairs	✓	✓	13.7	575
Kruskal–Wallis test	✓	✓	13.9	583
Friedman test	✓		13.10	589
Simple linear regression	✓	✓	14.2–14.7	631, 632, 660, 661, 668, 669
Multiple regression	✓	✓	15.1, 15.2, 15.4, 17.2 (b)	698, 713, 726, 823
Stepwise regression		✓	15.1	730
Multiple regression with indicator variables	✓		15.1 (extended)	785
Second-order polynomial regression	✓		16.2	778, 779

Key to Exercise/Case Icons

The exercises and cases illustrate how statistics can be used in a range of applications. When appropriate, the areas to which the cases and exercises apply are identified by the following icons:


Accounting


Computer Exercises/Cases


Economics


Education


Finance


Management


Marketing


Production/
Operations Management


Politics and Government


Real Estate


Retailing


Science/Health


Tourism

Preface

All statistics books describe how statistical techniques are performed. Most show in detail how to compute the statistics needed to make decisions, draw conclusions, or recommend actions. Most books also discuss the fundamental concepts underlying the statistical methods. However, we believe this is not enough. Presenting statistics as a series of unconnected arithmetic procedures produces students who will judge statistics courses boring, difficult, and useless. Showing students how to perform statistical techniques by hand does not prepare them for real-world applications or even the final exam in the course. Students' greatest difficulty is in identifying the correct statistical method to use. If students are taught only how to calculate statistics, they will be capable only of solving problems at the back of sections and chapters, because for those kinds of problems the student knows which technique to use—obviously the one introduced in that section or chapter. In this book we show not only the how and why of statistics but also the when.

Our philosophy in this book can be expressed quite simply: we regard the calculation of the statistical procedure to be the least important element of an application. Computers can more easily produce the results. Far more important is the ability to set up the problem properly, which includes recognizing which technique to use. Equally important is the ability to interpret the results and incorporate the statistics into the larger decision problem. This philosophy is made operational in several ways.

Systematic Approach

In Chapter 7 we introduce our systematic approach by describing the critical factors that determine the appropriate statistical technique. These are the problem objective and the type of data. We teach that all statistical techniques are fundamentally alike in that (except for nonparametric methods) we start by identifying the parameter of interest, the parameter's estimator, the estimator's sampling distribution, which leads to the confidence interval estimator, and the test statistic. Review Chapters 10 and 17, at the midpoint and conclusion of statistical inference, allow students to practice recognizing the correct method.

Realistic Applications

Applications of statistics in the real world or even in other courses often require the use of several different techniques. By emphasizing how to identify those techniques, we make it possible for instructors to introduce to their classes more interesting and realistic examples, exercises, and cases. Thus, it becomes easier to show students that statistics can be as useful as any other course in the curriculum. Students so convinced will be more motivated to learn statistics and less likely to find the course boring and difficult.

Use of the Computer

The availability of low cost computers and software has changed statistics. Because we no longer must demonstrate the arithmetic of statistics, we can spend our classroom time dealing with the concepts, discussing the exercises and cases, and in general motivating students. Even if students don't have access to computers and software, it is still unnecessary to present calculations by hand. Our approach allows instructors to discuss problem recognition and computer output interpretation without having to compute statistics by hand. You will find that most examples in this book present three different ways to solve the problem: we show how the calculations are done by hand (we believe that solving a few problems manually may provide a deeper understanding of the material), and we use the Minitab and SAS computer software systems to produce the statistical results. Thus, instructors may choose which form of solution to use. If they wish, instructors can easily substitute their preferred software output in place of our three methods.

In summary, we have attempted to make teaching and learning statistics a more positive experience. Our goal is to make the job that you do in the statistics class closely resemble the kind of work real statisticians do. Just as statisticians begin working on a problem by identifying which techniques to use, getting the computer to produce the results, and then incorporating these results into the decision framework, so too do our students perform the same operations on the examples, exercises, and cases. We've found that our students like this approach: they say it gives them more confidence and makes learning statistics more fun. We hope that all students have the same reaction to this textbook.

Learning Aids

Though we have mentioned several of the book's learning aids above, it may be useful to summarize them here:

Cases. There are 46 cases scattered throughout the book, which have been adapted from real studies. Students are expected to analyze the cases and draw conclusions in the same way as the authors of the studies. Some of the cases require the use of a computer and software. The data for these cases are stored on the disk for this book.

Computer Output. For most of the worked examples, we provide both Minitab and SAS output. This exposes students to how statistics is actually applied in the real world.

Minitab and SAS Instructions and Exercises. In the appendixes at the end of appropriate chapters, we provide instructions and commands for the actual use of these two popular packages. It is not necessary for students to purchase the Minitab or SAS manuals. We have also included exercises in those appendixes permitting students to practice using the software. The data for these exercises are stored on the data disk for this book.

Review Chapters. There are two review chapters in the text to help students identify the correct technique. Chapter 10 appears midway through our presentation of statistical

inference, and Chapter 17 reviews all of the statistical methods covered. Both feature flowcharts that summarize the systematic approach, as well as exercises and cases that require the use of several different statistical procedures.

Exercises. There are 1,136 exercises of varying levels of difficulty in this book:

Learning the Techniques Exercises appear at the end of most sections. These were developed to help students learn the arithmetic involved in a specific procedure.

Applying the Techniques Exercises follow. These stress when and why the technique is used and show how the results assist in the decision-making process.

Supplementary Exercises appear at the end of chapters. Because they cover all the topics presented in a particular chapter, they offer students practice in identifying which techniques to use of those they've encountered in that chapter. They also are more realistic and are somewhat more difficult than the other two types of exercises.

New in This Edition

This third edition features a number of improvements suggested by reviewers and users of the second edition:

1. The introduction to statistical inference has been altered. Chapter 5 in the second edition has been deleted. Chapter 7 now presents the concepts of estimation and hypothesis testing and illustrates them by discussing inference about the population mean when the population variance is known. Much of the material in the old Chapter 5 appears in the new Chapter 7. Chapter 8 describes the techniques used to make inferences about describing a single population. Chapter 9 presents statistical inference about comparing two populations.

2. The terms *nominal, ordinal,* and *interval data scales* have been replaced by *qualitative, ranked,* and *quantitative data.*

3. Graphical and numerical descriptive techniques have been separated into two chapters. In Chapter 2 we introduce graphical methods, and Chapter 3 presents numerical techniques.

4. Probability (Chapter 4) has been streamlined, concentrating only on the topics necessary to understand the foundation of statistical inference.

5. Throughout the book we have created new examples, exercises, and cases and deleted some others.

Teaching Aids

To assist professors, we have provided a number of teaching aids. All of these are available from Wadsworth Publishing Company.

An *Instructor's Resource Book* includes the following:

1. Suggestions about teaching statistics with the systematic approach.

2. Transparency Masters keyed to the teaching suggestions.

3. Teaching notes for each case, detailing the goals of the case, assignment questions, analysis and solution, teaching strategy, and (where necessary) Minitab computer instructions.

4. A write-up of supplementary topics that do not appear in the textbook but that some instructors may wish to cover (these have been formatted for easy reproduction and distribution to students):

- **a.** Joint probability distributions and covariance
- **b.** Hypergeometric distribution
- **c.** Continuous probability distributions with calculus
- **d.** Deriving the normal equations

5. SPSS instructions, which can be used instead of Minitab and SAS (these too can be copied and distributed).

6. A test bank containing about 800 problems and answers and a description of our approach to testing, including how we produce examinations that require no calculations for the students to perform. Computerized testing is also available in IBM-PC and Macintosh formats.

7. Detailed solutions for the textbook's odd-numbered exercises.

A *Student Solutions Manual* is also available. It furnishes detailed solutions for the textbook's even-numbered exercises.

Also for students is a *Study Guide* that contains overviews of each chapter in the text, examples illustrating specific techniques, and exercises and their solutions. There are a total of 134 worked examples and 324 exercises.

This book was developed from several courses we've taught in business and economics programs at a total of 10 universities over a combined 55 years of teaching. We are most grateful to our colleagues, our teaching assistants, and especially our students, whose helpful suggestions, comments, and criticisms have benefited this text.

The following reviewers also provided many valuable suggestions and comments: Kelly Black, *California State University, Fresno;* Ronald L. Coccari, *Cleveland State University;* Robert D. Curley, *Central State University;* Phyllis Curtiss, *Bowling Green State University;* Joaquin Diaz-Saiz, *University of Houston;* James Ford, *University of Southern California;* Damodar Golhar, *Western Michigan University;* Laura Grover, *California State University, Fullerton;* David Heinze, *California State University, Chico;* Morgan Jones, *University of North Carolina—Chapel Hill;* John Knox, *California State Polytechnic University, Pomona;* Charles Lienert, *Metropolitan State College;* Brenda Masters, *Oklahoma State University;* Kevin Murphy, *Oakland University;* Wayne Patterson, *Clemson University;* Leonard Presby, *Fairleigh Dickinson University;* Carl Quitmeyer, *George Mason University;* Donald Richter, *New York University;* Lillian Russell, *University of Delaware;* Dale G. Sauers, *York College;* Dale Shafer, *Indiana University—Pennsylvania;* Al Schainblatt, *San Francisco State University;* Stanley Schultz, *Cleveland State University;* Bala Shetty, *Texas A&M University;* Verne Stanton, *California State University, Fullerton;* Chipei P. Tseng, *Northern Illinois University;* Jim Willis, *Louisiana State University;* William Woodard; *University of Hawaii;* and Ben Zirkle, *Virginia Western Community College.*

Contents

CHAPTER 1

What Is Statistics?

SECTION 1.1 Introduction to Statistics

Statistics is a way to get information from data. That's it! Most of this textbook is devoted to describing how, when, and why managers and economists conduct statistical procedures. You may ask, if that's all there is to statistics, why this and most other statistics books are so large. The answer is that there are many different kinds of information and data to which students of applied statistics should be exposed. We demonstrate some of these with three cases that are featured later in this book.

CASE 8.1* National Patent Development Corporation

The National Patent Development Corporation (NPD) is a company that takes newly patented products from the design stage through to sales to the consumer. In 1986 NPD acquired a new product that can be used to replace the dentist's drill. The product, called Caridex, is a solution that dissolves decayed matter in dental cavities without requiring drilling. After some research it was discovered that Caridex works well only on cavities on the top surface of teeth, where a small fraction of cavities occur.

It is known that 100,000 dentists in the United States treat cavities. A preliminary analysis revealed that only 10% of all dentists would use Caridex in the first year after its introduction.

The dispensing unit costs NPD $200, and it intends to sell the unit at cost price. The solution costs NPD $0.50 per cavity and will be sold to dentists at a price of $2.50 per cavity. Fixed annual costs are expected to be $4 million.

NPD would like an estimate of the profit it can expect in the first year of operation. Because NPD's profits will depend completely on the number of cavities treated with Caridex during the year, NPD commissioned a survey of 400 dentists who planned to use Caridex. Each dentist was asked how many cavities he or she anticipates treating with Caridex during an average week. The results are stored on the data disk for this book. (Some of these data are shown below.)

7	4	4	5	4	4	8	4	6	4	3	4	3
3	4	2	6	5	4	6	4	2	6	2	7	3
⋮												
8	3	4	6	4	4	1	3	3	3			

The data in this case are the numbers of cavities to be treated with Caridex by each of the 400 dentists who are part of this survey. The information we would ultimately like to acquire is an estimate of the first-year profits that NPD should expect from Caridex. The question we need to address is how to extract the required information from the data. One of the first things we need to be able to do is summarize the numbers. This is the function of **descriptive statistics**.

* Based on a report by Ladenburg Thalman, a large, New York–based investment firm.