GLOBAL EDITION

STATISTICS FOR BUSINESS AND ECONOMICS

Tenth Global Edition

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Statistics for Business and Economics

TENTH GLOBAL EDITION

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I dedicate this book to Sgt. Lawrence Martin Carlson, who gave his life in service to his country on November 19, 2006, and to his mother, Charlotte Carlson, to his sister and brother, Andrea and Douglas, to his children, Savannah, and Ezra, and to his nieces, Helana, Anna, Eva Rose, and Emily.

William L. Carlson

I dedicate this book to my husband, Jim, and to our family, Jennie, Ann, Renee, Jon, Chris, Jon, Hannah, Leah, Christina, Jim, Wendy, Marius, Mihaela, Cezara, Anda, and Mara Iulia.

Betty M. Thorne

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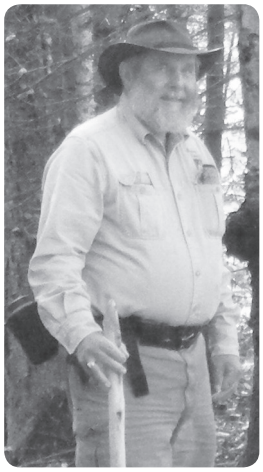

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PREFACE

Business statistics has continued to evolve as a discipline and has become an increasingly important part of business education programs. It is crucial *how* business statistics gets taught and *what* gets taught. *Statistics for Business and Economics, tenth edition*, has been written to meet the need for an introductory text that provides a strong introduction to business statistics, develops understanding of concepts, and emphasizes problem solving using realistic examples that use real data sets and computer based analysis. These examples highlight business and economics examples for the following:

- MBA or undergraduate business programs that teach business statistics
- Graduate and undergraduate economics programs
- Executive MBA programs
- Graduate courses for business statistics

Designed to build a strong foundation in applied statistical procedures, *Statistics for Business and Economics* enables individuals to perform solid statistical analysis in many business and economic situations. We have emphasized an understanding of the assumptions that are necessary for professional analysis. In particular we have greatly expanded the number of applications that utilize data from applied policy and research settings. These data and problem scenarios have been obtained from business analysts, major research organizations, and selected extractions from publicly available data sources. With data analysis software like Microsoft Excel, JMP, and Minitab, that illustrate how software can assist decision making process, it is now easy to compute, from the data, the output needed for many statistical procedures. It is tempting to merely apply simple "rules" using these outputs—an approach used in many textbooks. Our approach is to provide instruction through a combination of examples and exercises, supported by relevant software that show how understanding of methods and their assumptions lead to useful understanding of business and economic problems.

KEY FEATURES

The tenth edition of this book has been revised and updated to provide students with improved problem contexts for learning how statistical methods can improve their analysis and understanding of business and economics.

The objective of this revision is to provide a strong core textbook with new features and modifications that will provide an improved learning environment for students entering a rapidly changing technical work environment. This revision recognizes the globalization of statistical study and in particular the global market for this book.

1. Improvement in clarity and relevance of discussions of the core topics included in the book.
2. Addition of large databases developed by global public research agencies, businesses, and databases from the authors' own works.
3. An extensive number of new end-of-section or end-of-chapter problems.
4. Addition of a number of case studies, with both large and small sample sizes. Students are provided the opportunity to extend their statistical understanding to the context of research and analysis conducted by professionals. These studies include data files obtained from on-going research studies, which reduce for the student, the

extensive work load of data collection and refinement, thus providing an emphasis on question formulation, analysis, and reporting of results.
5. Careful revision of text and symbolic language to ensure consistent terms and definitions and to remove errors that accumulated from previous revisions and production problems.
6. Major revision of the discussion of Time Series both in terms of describing historical patterns and in the focus on identifying the underlying structure and introductory forecasting methods.
7. Integration of the text material, data sets, and exercises into new online applications including MyLab Statistics.
8. Expansion of descriptive statistics to include percentiles, z-scores, and alternative formulae to compute the sample variance and sample standard deviation.
9. Addition of a significant number of new examples based on real world data.
10. Greater emphasis on the assumptions being made when conducting various statistical procedures.
11. Reorganization of sampling concepts.
12. More detailed business-oriented examples and exercises incorporated in the analysis of statistics.
13. Improved chapter introductions that include business examples discussed in the chapter.
14. Good range of difficulty in the section ending exercises that permit the professor to tailor the difficulty level to his or her course.
15. Improved suitability for both introductory and advanced statistics courses for undergraduate and graduate students.
16. Decision Theory, which is covered in other business classes such as operations management or strategic management, has been moved to an online location for access by those who are interested (www.pearsonglobaleditions.com).

This edition devotes considerable effort to providing an understanding of statistical methods and their applications. We have avoided merely providing rules and canned computer routines for analyzing and solving statistical problems. This edition contains a complete discussion of methods and assumptions, including computational details expressed in clear and complete formulas. Through examples and extended chapter applications, we provide guidelines for interpreting results and explain how to determine if additional analysis is required. The development of the many procedures included under statistical inference and regression analysis are built on a strong development of probability and random variables, which are a foundation for the applications presented in this book. The foundation also includes a clear and complete discussion of descriptive statistics and graphical approaches. These provide important tools for exploring and describing data that represent a process being studied.

Probability and random variables are presented with a number of important applications, which are invaluable in management decision making. These include conditional probability and Bayesian applications that clarify decisions and show counterintuitive results in a number of decision situations. Linear combinations of random variables are developed in detail, with a number of applications of importance, including portfolio applications in finance.

The authors strongly believe that students learn best when they work with challenging and relevant applications that apply the concepts presented by dedicated teachers and the textbook. Thus the textbook has always included a number of data sets obtained from various applications in the public and private sectors. In the eighth edition we have added a number of large data sets obtained from major research projects and other sources. These data sets are used in chapter examples, exercises, and case studies located at the end of analysis chapters. A number of exercises consider individual analyses that are typically part of larger research projects. With this structure, students can deal with important detailed questions and can also work with case studies that require them to identify the detailed questions that are logically part of a larger research project. These large data sets can also be used by the teacher to develop additional research and case study projects that

are custom designed for local course environments. The opportunity to custom design new research questions for students is a unique part of this textbook.

A number of major data sets containing Taiwan's real estate measures, automobile fuel consumption, health data, the World Happiness Report (which captures the effects of COVID-19 on people's lives and evaluates how world governments dealt with the pandemic), New York's air quality index, and more are described in detail at the end of the chapters where they are used in exercises and case studies. A complete list of the data files and where they are used is located at the end of this preface. Data files are also shown by chapter at the end of each chapter.

The book provides a complete and in-depth presentation of major applied topics. An initial read of the discussion and application examples enables a student to begin working on simple exercises, followed by challenging exercises that provide the opportunity to learn by doing relevant analysis applications. Chapters also include summary sections, which clearly present the key components of application tools. Many analysts and teachers have used this book as a reference for reviewing specific applications. Once you have used this book to help learn statistical applications, you will also find it to be a useful resource as you use statistical analysis procedures in your future career.

A number of special applications of major procedures are included in various sections. Clearly there are more than can be used in a single course. But careful selection of topics from the various chapters enables the teacher to design a course that provides for the specific needs of students in the local academic program. Special examples that can be left out or included provide a breadth of opportunities. The initial probability chapter, Chapter 3, provides topics such as decision trees, overinvolvement ratios, and expanded coverage of Bayesian applications, any of which might provide important material for local courses. Confidence interval and hypothesis tests include procedures for variances and for categorical and ordinal data. Random-variable chapters include linear combination of correlated random variables with applications to financial portfolios. Regression applications include estimation of beta ratios in finance, dummy variables in experimental design, nonlinear regression, and many more.

As indicated here, the book has the capability of being used in a variety of courses that provide applications for a variety of academic programs. The other benefit to the student is that this textbook can be an ideal resource for the student's future professional career. The design of the book makes it possible for a student to come back to topics after several years and quickly renew his or her understanding. With all the additional special topics, that may not have been included in a first course, the book is a reference for learning important new applications. And the presentation of those new applications follows a presentation style and uses understandings that are familiar. This reduces the time required to master new application topics.

APPLYING CONCEPTS

We understand how important it is for students to know statistical concepts and apply those to different situations they face everyday or will face as managers of the future. Almost all sections include examples that illustrate the application of the concepts or methods of that section to a real-world context (even though the company or organization may be hypothetical). Problems are structured to present the perspective of a decision maker and the analysis provided is to help understand the use of statistics in a practical way.

PROMOTING PROBLEM ANALYSIS

This book includes section Exercises and chapter Exercises and Applications. The section exercises for each chapter begin with straightforward exercises targeted at the topics in each section. These are designed to check understanding of specific topics. Because they appear after each section, it is easy to turn back to the chapter to clarify a concept or review a method. The Chapter Exercises and Applications are designed to lead to conclusions

about the real world and are more application-based. They usually combine concepts and methods from different sections.

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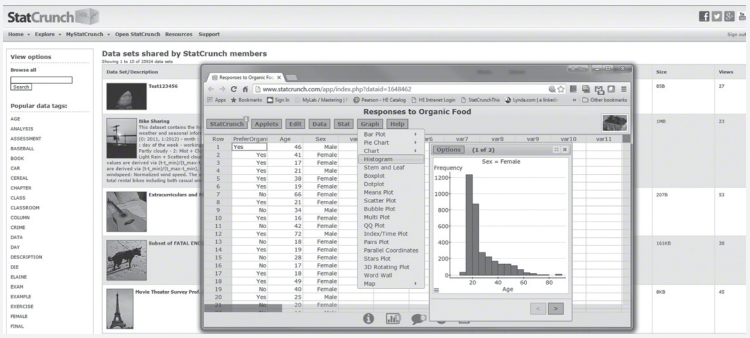

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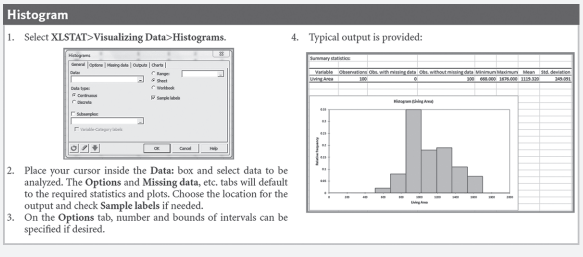

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CHAPTER

1

Describing Data: Graphical

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Measurement Levels
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1.6 Data Presentation Errors
Misleading Histograms
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Introduction

What are the projected sales of a new product? Will the cost of Google shares continue to increase? Who will win the 2020 UEFA Champions League? How satisfied were you with your last purchase at Starbucks, on alibaba.com, or at IKEA? If you were hired by the National Nutrition Council of your country, how would you determine if the Council's guidelines on consumption of fruit, vegetables, snack foods, and soft drinks are being met? Do people who are physically active have healthier diets than people who are not physically active? What factors (perhaps disposable income or grants) are significant in forecasting the aggregate consumption of durable goods? What effect will a 2% increase in interest rates have on residential investment? Do

credit scores, current balance, or outstanding maintenance balance contribute to an increase in the percentage of a mortgage company's delinquent accounts increasing? Answers to questions such as these come from an understanding of statistics, fluctuations in the market, consumer preferences, trends, and so on.

Statistics are used to predict or forecast sales of a new product, construction costs, customer-satisfaction levels, the weather, election results, university enrollment figures, grade point averages, interest rates, currency-exchange rates, and many other variables that affect our daily lives. We need to absorb and interpret substantial amounts of data. Governments, businesses, and scientific researchers spend billions of dollars collecting data. But once data are collected, what do we do with them? How do data impact decision making?

In our study of *statistics* we learn many tools to help us process, summarize, analyze, and interpret data for the purpose of making better decisions in an uncertain environment. Basically, an understanding of statistics will permit us to make sense of all the data.

In this chapter we introduce tables and graphs that help us gain a better understanding of data and that provide visual support for improved decision making. Reports are enhanced by the inclusion of appropriate tables and graphs, such as frequency distributions, bar charts, pie charts, Pareto diagrams, line charts, histograms, stem-and-leaf displays, or ogives. Visualization of data is important. We should always ask the following questions: What does the graph suggest about the data? What is it that we see?

1.1 Decision Making in an Uncertain Environment

Decisions are often made based on limited information. Accountants may need to select a portion of records for auditing purposes. Financial investors need to understand the market's fluctuations, and they need to choose between various portfolio investments. Managers may use surveys to find out if customers are satisfied with their company's products or services. Perhaps a marketing executive wants information concerning customers' taste preferences, their shopping habits, or the demographics of Internet shoppers. An investor does not know with certainty whether financial markets will be buoyant, steady, or depressed. Nevertheless, the investor must decide how to balance a portfolio among stocks, bonds, and money market instruments while future market movements are unknown.

For each of these situations, we must carefully define the problem, determine what data are needed, collect the data, and use statistics to summarize the data and make inferences and decisions based on the data obtained. Statistical thinking is essential from initial problem definition to final decision, which may lead to reduced costs, increased profits, improved processes, and increased customer satisfaction.

Random and Systematic Sampling

Before bringing a new product to market, a manufacturer wants to arrive at some assessment of the likely level of demand and may undertake a market research survey. The manufacturer is, in fact, interested in *all* potential buyers (the population). However, populations are often so large that they are unwieldy to analyze; collecting complete information for a population could be impossible or prohibitively expensive. Even in circumstances where sufficient resources seem to be available, time constraints make the examination of a subset (sample) necessary.

Population and Sample

A **population** is the complete set of all items that interest an investigator. Population size, N, can be very large or even infinite. A **sample** is an observed subset (or portion) of a population with sample size given by n.

Examples of populations include the following:

- All potential buyers of a new product
- All stocks traded on the London Stock Exchange (LSE)
- All registered voters in a particular city or country
- All accounts receivable for a corporation

Our eventual aim is to make statements based on sample data that have some validity about the population at large. We need a sample, then, that is representative of the population. How can we achieve that? One important principle that we must follow in the sample selection process is randomness.

Random Sampling

Simple random sampling is a procedure used to select a sample of n objects from a population in such a way that each member of the population is chosen strictly by chance, the selection of one member does not influence the selection of any other member, each member of the population is equally likely to be chosen, and every possible sample of a given size, n, has the same chance of selection. This method is so common that the adjective *simple* is generally dropped, and the resulting sample is called a **random sample**.

Another sampling procedure is systematic sampling (stratified sampling and cluster sampling are discussed in Chapter 17).

Systematic Sampling

Suppose that the population list is arranged in some fashion unconnected with the subject of interest. **Systematic sampling** involves the selection of every jth item in the population, where j is the ratio of the population size N to the desired sample size, n; that is, $j = N/n$. Randomly select a number from 1 to j to obtain the first item to be included in your systematic sample.

Suppose that a sample size of 100 is desired and that the population consists of 5,000 names in alphabetical order. Then $j = 50$. Randomly select a number from 1 to 50. If your number is 20, select it and every 50th number, giving the systematic sample of elements numbered 20, 70, 120, 170, and so forth, until all 100 items are selected. A systematic sample is analyzed in the same fashion as a simple random sample on the grounds that, relative to the subject of inquiry, the population listing is already in random order. The danger is that there could be some subtle, unsuspected link between the ordering of the population and the subject under study. If this were so, bias would be induced if systematic sampling was employed. Systematic samples provide a good representation of the population if there is no cyclical variation in the population.

Sampling and Nonsampling Errors

Suppose that we want to know the average age of registered voters in the United States. Clearly, the population size is so large that we might take only a random sample, perhaps 500 registered voters, and calculate their average age. Because this average is based on sample data, it is called a *statistic*. If we were able to calculate the average age of the entire population, then the resulting average would be called a *parameter*.

Parameter and Statistic

A **parameter** is a numerical measure that describes a specific characteristic of a population. A **statistic** is a numerical measure that describes a specific characteristic of a sample.

Throughout this book we will study ways to make decisions about a population parameter, based on a sample statistic. We must realize that some element of uncertainty will always remain, as we do not know the exact value of the parameter. That is, when a sample is taken from a population, the value of any population parameter will not be able to be known *precisely*. One source of error, called **sampling error**, results from the fact that information is available on only a subset of all the population members. In Chapters 6, 7, and 8 we develop statistical theory that allows us to characterize the nature of the sampling error and to make certain statements about population parameters.

In practical analyses there is the possibility of an error unconnected with the kind of sampling procedure used. Indeed, such errors could just as well arise if a complete census of the population were taken. These are referred to as **nonsampling errors**. Examples of nonsampling errors include the following:

1. ***The population actually sampled is not the relevant one.*** A celebrated instance of this sort occurred in 1936, when *Literary Digest* magazine confidently predicted that Alfred Landon would win the presidential election over Franklin Roosevelt. However, Roosevelt won by a very comfortable margin. This erroneous forecast resulted from the fact that the members of the *Digest's* sample had been taken from telephone directories and other listings, such as magazine subscription lists and automobile registrations. These sources considerably underrepresented the poor, who were predominantly Democrats. To make an inference about a population (in this case the U.S. electorate), it is important to sample that population and not some subgroup of it, however convenient the latter course might appear to be.
2. ***Survey subjects may give inaccurate or dishonest answers.*** This could happen because questions are phrased in a manner that is difficult to understand or in a way that appears to make a particular answer seem more palatable or more desirable. Also, many questions that one might want to ask are so sensitive that it would be foolhardy to expect uniformly honest responses. Suppose, for example, that a plant manager wants to assess the annual losses to the company caused by employee thefts. In principle, a random sample of employees could be selected and sample members asked, What have you stolen from this plant in the past 12 months? This is clearly not the most reliable means of obtaining the required information!
3. ***There may be no response to survey questions.*** Survey subjects may not respond at all, or they may not respond to certain questions. If this is substantial, it can induce additional sampling and nonsampling errors. The sampling error arises because the achieved sample size will be smaller than that intended. Nonsampling error possibly occurs because, in effect, the population being sampled is not the population of interest. The results obtained can be regarded as a random sample *from the population that is willing to respond*. These people may differ in important ways from the larger population. If this is so, a bias will be induced in the resulting estimates.

There is no general procedure for identifying and analyzing nonsampling errors. But nonsampling errors could be important. The investigator must take care in such matters as identifying the relevant population, designing the questionnaire, and dealing with nonresponse in order to minimize the significance of nonsampling errors. In the remainder of this book it is assumed that such care has been taken, and our discussion centers on the treatment of sampling errors.

To think statistically begins with problem definition: (1) What information is required? (2) What is the relevant population? (3) How should sample members be selected? (4) How should information be obtained from the sample members? Next we will want to know how to use sample information to make decisions about our population of interest. Finally, we will want to know what conclusions can be drawn about the population.

After we identify and define a problem, we collect data produced by various processes according to a design, and then we analyze that data using one or more statistical procedures. From this analysis, we obtain information. Information is, in turn, converted into knowledge, using understanding based on specific experience, theory, literature, and additional statistical procedures. Both descriptive and inferential statistics are used to change data into knowledge that leads to better decision making. To do this, we use descriptive statistics and inferential statistics.

Descriptive and Inferential Statistics

Descriptive statistics focus on graphical and numerical procedures that are used to summarize and process data. **Inferential statistics** focus on using the data to make predictions, forecasts, and estimates to make better decisions.

1.2 Classification of Variables

A variable is a specific characteristic (such as age or weight) of an individual or object. Variables can be classified in several ways. One method of classification refers to the type and amount of information contained in the data. Data are either categorical or numerical. Another method, introduced in 1946 by American psychologist Stanley Smith Stevens is to classify data by levels of measurement, giving either qualitative or quantitative variables. Correctly classifying data is an important first step to selecting the correct statistical procedures needed to analyze and interpret data.

Categorical and Numerical Variables

Categorical variables produce responses that belong to groups or categories. For example, responses to yes/no questions are categorical. Are you a business major? and Do you own a car? are limited to yes or no answers. A health care insurance company may classify incorrect claims according to the type of errors, such as procedural and diagnostic errors, patient information errors, and contractual errors. Other examples of categorical variables include questions on gender or marital status. Sometimes categorical variables include a range of choices, such as "strongly disagree" to "strongly agree." For example, consider a faculty-evaluation form where students are to respond to statements such as the following: The instructor in this course was an effective teacher (1: strongly disagree; 2: slightly disagree; 3: neither agree nor disagree; 4: slightly agree; 5: strongly agree).

Numerical variables include both discrete and continuous variables. A **discrete numerical variable** may (but does not necessarily) have a finite number of values. However, the most common type of discrete numerical variable produces a response that comes from a counting process. Examples of discrete numerical variables include the number of students enrolled in a class, the number of university credits earned by a student at the end of a particular semester, and the number of Microsoft stocks in an investor's portfolio.

A **continuous numerical variable** may take on any value within a given range of real numbers and usually arises from a measurement (not a counting) process. Someone might say that he is 6 feet (or 72 inches) tall, but his height could actually be 72.1 inches, 71.8 inches, or some other similar number, depending on the accuracy of the instrument used to measure height. Other examples of continuous numerical variables include the weight of a cereal box, the time to run a race, the distance between two cities, or the temperature. In each case the value could deviate within a certain amount, depending on the precision of the measurement instrument used. We tend to truncate continuous variables in daily conversation and treat them as though they were the same as discrete variables without even giving it a second thought.

Measurement Levels

We can also describe data as either *qualitative* or *quantitative*. With **qualitative data** there is no measurable meaning to the "difference" in numbers. For example, one football player is assigned the number 7 and another player has the number 10. We cannot conclude that the first player plays twice as well as the second player. However, with **quantitative data** there is a measurable meaning to the difference in numbers. When one student scores 90 on an exam and another student scores 45, the difference is measurable and meaningful.

Qualitative data include nominal and ordinal levels of measurement. Quantitative data include interval and ratio levels of measurement.

Nominal and ordinal levels of measurement refer to data obtained from categorical questions. Responses to questions on gender, country of citizenship, political affiliation, and ownership of a mobile phone are nominal. **Nominal data** are considered the lowest or weakest type of data, since numerical identification is chosen strictly for convenience and does not imply ranking of responses.

The values of nominal variables are words that describe the categories or classes of responses. The values of the gender variable are male and female; the values of Do you own a car? are yes and no. We arbitrarily assign a code or number to each response. However, this number has no meaning other than for categorizing. For example, we could code gender responses or yes/no responses as follows:

1 = Male; 2 = Female
1 = Yes; 2 = No

Ordinal data indicate the rank ordering of items, and similar to nominal data the values are words that describe responses. Some examples of ordinal data and possible codes are as follows:

1. Product quality rating (1: poor; 2: average; 3: good)
2. Satisfaction rating with your current Internet provider (1: very dissatisfied; 2: moderately dissatisfied; 3: no opinion; 4: moderately satisfied; 5: very satisfied)
3. Consumer preference among three different types of soft drink (1: most preferred; 2: second choice; 3: third choice)

In these examples the responses are ordinal, or put into a rank order, but there is no measurable meaning to the "difference" between responses. That is, the difference between your first and second choices may not be the same as the difference between your second and third choices.

Interval and ratio levels of measurement refer to data obtained from numerical variables, and meaning is given to the *difference* between measurements. An interval scale indicates rank and distance from an arbitrary zero measured in unit intervals. That is, data are provided relative to an arbitrarily determined benchmark. Temperature is a classic example of this level of measurement, with arbitrarily determined benchmarks generally based on either Celsius degrees or Fahrenheit. Suppose that in March 2019, it is 30°C in Pune, India, and only 10°C in Tokyo, Japan. We can conclude that the difference in temperature is 20°, but we cannot say that it is three times as warm in Pune as it is in Tokyo. The year is another example of an interval level of measurement, with benchmarks based most commonly on the Gregorian calendar.