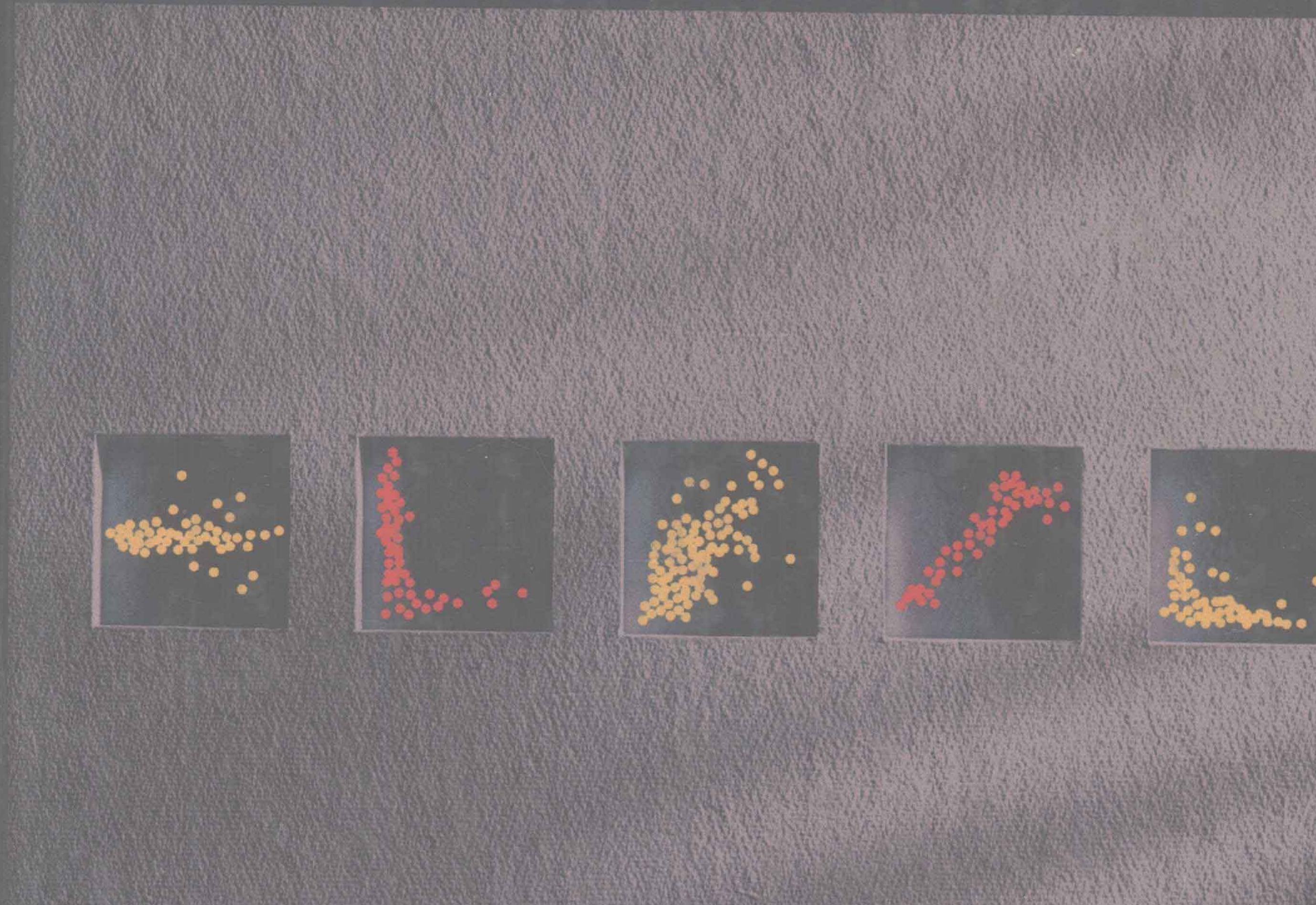
Applied Regression Analysis

for Business and Economics *Third Edition*



Terry Dielman

APPLIED REGRESSION ANALYSIS

FOR BUSINESS AND ECONOMICS

THIRD EDITION

Terry E. Dielman

M. J. Neeley School of Business
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Preface

Applied Regression Analysis for Business and Economics is designed for a one-semester course in regression analysis for business and economics undergraduates and MBAs. The goal of the text is to present regression concepts and techniques in a way that avoids unnecessary mathematical rigor. The emphasis is on understanding the assumptions of the regression model, knowing how to validate a selected model for these assumptions, knowing when and how regression might be useful in a business setting, and understanding and interpreting output from statistical packages and spreadsheets. The text presents output from the statistical package MINITAB and the spreadsheet Microsoft® Excel. In the Using the Computer section at the end of each chapter, the MINITAB and Excel procedures used to perform the analyses shown in the chapter are presented. In addition, SAS commands for the procedures are shown, although SAS output is not included in the text. A brief general introduction to MINITAB, Excel, and SAS is presented in Appendix C. Other statistical packages and spreadsheets containing regression procedures can also be easily used with the text.

Level and Prerequisites

To use the text, little mathematical expertise beyond basic college algebra is necessary. No knowledge of linear algebra is assumed. Appendix D does provide a summary of matrices and matrix operations and a brief introduction to the use of matrices in presenting the least-squares method for the interested reader. An introductory (or first semester) course in statistics is assumed. Chapter 2 does, however, contain a brief review of most of the concepts covered in an introductory statistics course.

It is assumed throughout the text that students have access to a computer and statistical software. The text concentrates on using the computer to do the calculations, but the student is responsible for knowing what to do with the resulting computer output. Although the text could be used without computer access, the author believes that actually analyzing data is an important component of the learning process.

Real Data

Actual data drawn from various sources are used throughout the book in the examples and exercises. When data are simulated, an attempt has been made to provide realistic data and situations in which these data might occur. In this way, the relevance of the techniques being presented is highlighted for students.

Data sets for the exercises in this text can be accessed by going to the Web site www.duxbury.com and selecting "Data Library." Select this textbook, and then select the file format needed. Available file formats include Excel, MINITAB, SAS, and SPSS. Filename prefixes needed to read the data are shown with each exercise. The filename prefixes are the same regardless of the format. Only the filename suffixes differ. More information on accessing the data files is available on the endsheets of the text.

Organization and Coverage

Chapter 2 provides a quick review of most concepts covered in a first-semester statistics course. Chapters 3 through 8 provide the material on linear regression. Chapter 3 introduces simple linear regression, including MINITAB and Excel regression output. Chapter 4 provides the extension to multiple linear regression. Chapter 5 discusses the fitting of curves with regression. Chapter 6 discusses the implications of violations of assumptions of the regression model, presents ways to recognize possible violations, and suggests corrections for violations. Chapter 7 describes the use of indicator and interaction variables. Chapter 8 discusses several techniques used to aid in selecting explanatory variables for the regression.

Chapters 9 and 10 can be viewed as optional in a course on linear regression. Chapter 9 presents a brief introduction to analysis of variance. One-way analysis of variance and its relationship to regression with indicator variables are discussed. The chapter concludes with an examination of randomized block designs and two-way complete factorial designs. Chapter 10 introduces two procedures that can be used when qualitative dependent variables are encountered: discriminant analysis and logistic regression. The chapter concentrates on the two-group case.

Changes in the Third Edition

These are the major changes in the third edition:

- Most of the data sets in the text have been updated. Additional problems and examples involving real data have been added to the text. Some of these data sets come from actual business settings, while others are taken from journals and popular publications.
- Excel output is included in addition to MINITAB output.
- Chapter 5 of the second edition has been split into two parts. These two parts now make up Chapters 5 and 6. The new Chapter 5 discusses fitting curves with regression. The new Chapter 6 discusses the implications of violations of assumptions of the regression model, presents ways to recognize possible violations, and suggests corrections for violations. Reviews of the second edition of the text suggested that Chapter 5 was too long and was somewhat unwieldy for students. In addition, this

new structure allows the instructor to present curve-fitting as part of multiple regression rather than as a response to violation of an assumption. Reviews of the second edition indicated this was a desired option for many instructors.

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Fort Worth

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CHAPTER 1

An Introduction to Regression Analysis

Advances in technology including computers, scanners, and telecommunications equipment have buried present-day managers under a mountain of data. Although the purpose of these data is to assist managers in the decision-making process, corporate executives who face the task of juggling data on many variables may find themselves at a loss when attempting to make sense of such information. The decision-making process is further complicated by the dynamic elements in the business environment and the complex interrelationships among these elements.

This text has been prepared to give managers (and future managers) tools for examining possible relationships between two or more variables. For example, sales and advertising are two variables commonly thought to be related. When a soft drink company increases advertising expenditures by paying professional athletes millions of dollars to do its advertisements, it expects this outlay to increase sales. In general, when decisions on advertising expenditures of millions of dollars are involved, it is comforting to have some evidence that, in the past, increased advertising expenditures indeed led to increased sales.

Another example is the relationship between the selling price of a house and its square footage. When a new house is listed for sale, how should the price be determined? Is a 4000-square-foot house worth twice as much as a 2000-square-foot house? What other factors might be involved in the pricing of houses and how should these factors be included in the determination of the price?

In a study of absenteeism at a large manufacturing plant, management may feel that several variables have an impact. These variables might include job complexity, base pay, the number of years the worker has been with the plant, and the age of that worker. If absenteeism can cost the company thousands of dollars, then the importance of identifying its associated factors becomes clear.

Perhaps the most important analytic tool for examining the relationships between two or more variables is regression analysis. *Regression analysis* is a statistical technique for developing an equation describing the relationship between two or more variables. One variable is specified to be the *dependent variable*, or the variable to be explained. The other one or more variables are called the *independent* or *explanatory variables*. Using the previous examples, the soft drink firm would identify sales as the dependent variable and advertising expenditures as the explanatory variable. The real estate firm would choose selling price as the dependent variable and size as the explanatory variable to explain variations in selling price from house to house.

There are several reasons business researchers might want to know how certain variables are related. The retail firm may want to know how much advertising is necessary to achieve a certain level of sales. An equation expressing the relationship between sales and advertising is useful in answering this question. For the real estate firm, the relationship might be used in assigning prices to houses coming onto the market. To try to lower the absenteeism rate, the management of the manufacturing firm wants to know what variables are most highly related to absenteeism. Reasons for wanting to develop an equation relating two or more variables can be classified as follows: (a) to describe the relationship, (b) for control purposes (what value of the explanatory variable is needed to produce a certain level of the dependent variable), or (c) for prediction.

Much statistical analysis is a multistage process of trial and error. A good deal of exploratory work must be done to select appropriate variables for study and to determine the relationships between or among them. This requires that a variety of statistical tests and other procedures be performed and sound judgments be made before one arrives at satisfactory choices of dependent and explanatory variables. The emphasis in this text is on this multistage process rather than on the computations themselves or an in-depth study of the theory behind the techniques presented. In this sense, the text is directed at the applied researcher or the consumer of statistics.

Except for a few preparatory examples, it is assumed that a computer is available to the reader to perform the actual computations. The use of statistical software frees the user to concentrate on the multistage "model-building" process.

Most examples use illustrative computer output to present the results. The two software packages used are MINITAB™ (Version 12) and Microsoft® Excel 2000. MINITAB is included because it is widely used as a teaching tool in universities and is also used in industry. Excel is included because it is the prevalent spreadsheet available in businesses throughout the world. In a business environment, not all managers have access to a statistical package, but nearly all have access to a spreadsheet package, and that package is usually Excel. Knowing how to perform statistical routines with Excel enables the manager without a statistical package to conduct some statistical analyses. The output from MINITAB and Excel is fairly standard and easily understood. Many of the exercises are intended to be done with the aid of a computer. Most statistical software packages or spreadsheets could be used for this purpose. Some of the options available in MINITAB and Excel may not be present in other packages, but this should not create a problem in completing the exercises.

One note of caution at this point: Excel is a spreadsheet and was not created specifically for statistical analysis. It can be useful for many analyses, but it cannot take the place of a true statistical package such as MINITAB or SAS®. If you are involved in a substantial amount of data analysis, I recommend using a statistical package rather than a spreadsheet for this purpose. Throughout this text, there are many examples of regression analysis where Excel and MINITAB are used on the same data set. In all cases in this text, Excel produces the same answers as MINITAB. I have, however, heard that on certain types of analyses of some data sets, Excel may fail to produce correct answers. The data sets where this occurs are likely to be those that impose a severe computational burden on Excel. I have not seen this occur personally with Excel 2000, but the reader is cautioned to make sure the results of any analysis make sense. Results that are contrary to intuition should be called into question and verified with a statistical package. There are also procedures that are useful in more advanced analyses that are not available in Excel. These require the use of a package specifically designed for statistical analysis.

Data sets for the exercises in this text are available on a Web site. Instructions for downloading the data files are given in the preface and on the endsheets of this text. Data sets are provided in either MINITAB files or Excel spreadsheets. In addition, SAS and SPSS files are provided for users of these statistical packages, and ASCII files are provided for general use in other packages. In each problem where data sets are provided, the file names required to read the data are given. The filenames are the same regardless of the file format. Only the file name suffixes differ.

A section called Using the Computer is included at the end of each chapter. The procedures used in MINITAB, Excel, and SAS to produce the statistical analyses discussed in each chapter are presented there. SAS is often the package of choice in industry for statistical analysis. SAS output has not been included in this edition of the text, but the output from SAS is very similar to that of MINITAB, and the interpretation of SAS output should be easily accomplished by students. Appendix C provides a brief, general discussion of the use of MINITAB, Excel, and SAS. This book, however, is not intended to provide full information on the use of these software packages. For further information on MINITAB, Excel, and SAS, the interested reader is referred to one of the following references:

Berk, K., and Carey, P. *Data Analysis with Microsoft® Excel.* Pacific Grove, CA: Duxbury Press, 2000.

Carver, R. *Doing Data Analysis with MINITAB™ 12.* Pacific Grove, CA: Duxbury Press, 1999.

Freund, R., and Littell, R. *SAS® System for Regression* (2nd ed.). Cary, NC: SAS Institute, 1991.

Lehmann, M., and Zeitz, P. *Statistical Explorations with Microsoft® Excel.* Pacific Grove, CA: Duxbury Press, 1998.

McKenzie, J., and Goldman, R. *The Student Edition of MINITAB™.* Reading, MA.: Addison-Wesley, 1998.

MINITAB User's Guide, Release 12 for Windows®. State College, PA: MINITAB™, Inc., February 1998.

Neufeld, J. *Learning Business Statistics with Microsoft® Excel.* Upper Saddle River, NJ: Prentice Hall, 1997.

CHAPTER 2

Review of Basic Statistical Concepts

2.1 INTRODUCTION

This chapter summarizes and reviews many of the basic statistical concepts taught in an introductory statistics course. For the most part, introductory courses in statistics deal with three main areas of interest: descriptive statistics, probability, and statistical inference.

Typically, the problem in statistics is one of studying a particular population. A *population,* for purposes of this text, may be defined as the collection of all items of interest to a researcher. The researcher may want to study the sales figures for firms in a particular industry, the rates of return on public utility firms, or the lifetimes of a new brand of automobile tires. But because of time limitations, cost, or the destructive nature of testing, it is not always possible to examine all elements in a population. Instead, a subset of the population, called a *sample,* is chosen, and the characteristic of interest is determined for the items in the sample.

Descriptive statistics is that area of statistics that summarizes the information contained in a sample. This summary may be achieved by condensing the information and presenting it in tabular form. For example, frequency distributions are one way to summarize data in a table. Graphical methods of summarizing data also may be used. The types of graphs discussed in introductory statistics courses include histograms, pie charts, bar charts, and scatterplots.

Data also may be summarized by numerical values. For example, to describe the center of a data set, the mean or median is often suggested. To describe variability, the variance, standard deviation, or interquartile range might be used. Each of the numerical values is a single number computed from the data that describes a certain characteristic of a sample.

Describing the information contained in a sample is only a first step for most statistical studies. If the study of a population's characteristics is the researcher's goal, then he or she wants to use the information obtained from the sample to make statements about the population. The process of generalizing from characteristics of a sample to those of a population is called *statistical inference.* The bridge leading from descriptive measures computed for a sample to inferences made about population characteristics is the field of probability.

Statistical sampling is an additional topic discussed in introductory statistics. By choosing the elements of a sample in a particular manner, objective evaluations can be made of the quality of the inferences concerning population characteristics. Without proper choice of a sample, inferences can be made, but there is no way to evaluate these generalizations objectively. Thus, the manner in which the sample is chosen is important.

The most common type of sampling procedure discussed in introductory statistics is simple random sampling. Suppose a sample of n items is desired. To qualify as a *simple random sample* (SRS), the items in the sample are selected so that each possible sample of size n is equally likely to be chosen. In other words, each possible sample has an equal probability of being the one actually chosen. This is one of the pieces of the bridge that links descriptive statistics and statistical inference. Another piece of the bridge is a description of the behavior of certain numerical summaries that are computed as descriptive statistics.

Any numerical summary computed from a sample is called a *statistic.* A researcher may compute a single statistic from one sample chosen from the population of interest and use the numerical value of this statistic to make a statement about the value of some population characteristic. For example, suppose a particular brand of tires is to be studied to determine their average life. If the average life is known, the tire company might use this information to establish a warranty for its tires. An SRS of n tires is chosen, and each tire is tested to determine its individual lifetime. Then the sample average lifetime is computed. This sample average can be used as an estimate of the population average lifetime of these tires.

The statistic computed, however, is the sample average lifetime for one particular sample of tires chosen. If a different set of n tires had been chosen, a different sample average would have resulted because of individual variation in the tires' lifetimes. Thus, the sample means themselves vary depending on which set of n tires is chosen as the sample. If this variation in the sample means was without any pattern, then there is no way to relate the value of the sample mean obtained to the unknown value of the population mean. Fortunately, the behavior of the sample means (and other statistics) from random samples is not without a pattern. The behavior of statistics is described by a concept called a *sampling distribution.* Probability enters the picture because sampling distributions are simply probability distributions. Through knowledge of the sampling distribution of a statistic, procedures can be developed to objectively evaluate the quality of sample statistics used to approximate population characteristics.

In this chapter, many of the concepts mentioned previously are reviewed. These include descriptive statistics, random variables and probability distributions, sampling distributions, and statistical inference. Because most or all of these topics are covered in an introductory course in statistics, the coverage here is brief.

For detailed references on introductory statistics, the interested reader is referred to texts such as:

Albright, S., Winston, W., and Zappe, C. *Data Analysis and Decision Making with Microsoft® Excel.* Pacific Grove, CA: Duxbury Press, 1999.

Brightman, H. *Data Analysis in Plain English with Excel.* Pacific Grove, CA: Duxbury Press, 1999.

Hildebrand, D., and Ott, R. *Statistical Thinking for Managers* (4th ed.). Pacific Grove, CA: Duxbury Press, 1998.

Keller, G., and Warrack, B. *Statistics for Management and Economics* (5th ed.). Pacific Grove, CA: Duxbury Press, 2000.

2.2 DESCRIPTIVE STATISTICS

Table 2.1 shows the 5-year returns as of June 14, 1999, for a random sample of 60 mutual funds. Examining the 60 numbers in this list provides little useful information. Just looking at a list of numbers is confusing even when the sample size is only 60. For larger samples, the confusion becomes even greater.

The field of descriptive statistics provides ways to summarize the information in a data set. Summaries can be tabular, graphical, or numerical. One common tabular method of summarizing data is the frequency distribution. A *frequency distribution* is a table that is used to summarize quantitative data. The frequency distribution is set up by defining *bins* or *classes* that contain the data values. An examination of the returns in Table 2.1 shows that the largest 5-year rate of return is 40.9% and the smallest is –14.2%. We want to make sure that we include all the data in our frequency distribution, so the bins of the frequency distribution must begin at or below the smallest value and end at or above the largest. One example of how we might set up the frequency distribution is as follows: Start the first bin at –20.0%, end the last bin at 50.0%, and use a total of seven bins. The resulting frequency distribution is shown in Figure 2.1.

Note that the bins are set up in such a way that there is no confusion about where a data value should go. Each bin includes the lower limit, but excludes the upper limit. A 5-year return of 4% belongs in the third bin; a 20% return belongs in the fifth bin. Also note that each of the bins has the same width: 10%. Two guidelines for constructing an effective frequency distribution are (a) make sure each data value belongs in a unique bin and (b) if possible, make each bin width the same. Intervals covering the range of the data are constructed, and the number of observations in each interval is then tabulated and recorded.

TABLE 2.1 **Five-Year Rates of Return for Mutual Funds**

Mutual Fund	5-Year Return	Mutual Fund	5-Year Return
Accessor Small to Midcap	21.90	MAS Balanced Instl.	16.70
AIM Advisor Flex Fund C	16.20	Meridian Fund	12.70
Alliance Growth Investors A	15.60	MFS Research A	21.20
American Century Giftrust	9.50	Mutual Beacon Z	17.40
American Express IDS Growth A	24.70	Neuberger & Berman Focus	18.60
Ariel Fund	16.80	Northern Select Equity	24.30
BB&T Growth & Income A	20.10	One Group Diversified A	21.90
Brandywine Fund	15.70	Oppenheimer Quest Opportunity Value A	18.90
Chase Vista Equity Income A	20.70	Parkstone Small Cap A	13.00
Columbia Special	13.90	Phoenix-Goodwin Strategic Allocation A	9.70
DLJ Winthrop Small Company Value A	10.00	PIMCO StocksPlus Instl	26.40
Dreyfus Premier Aggressive Growth A	–8.00	Principal Balanced A	12.90
Dreyfus Small Company Value	18.80	Putnam Convertible Income Gro A	14.30
Enterprise Growth A	27.40	Rainier Investment Balanced	17.70
Excelsior Value & Restructuring	24.30	Rydex OTC	40.90
Fidelity Asset Manager Fund	13.40	Scudder Development	17.10
Fidelity Capital Appreciation	18.60	Sentinel Common Stock A	19.80
Fidelity Puritan	15.10	Smith Barney Concert Growth 1	21.30
Fidelity Select Home Finance	18.30	Standish Equity	19.30
First Investors Blue Chip A	19.80	STI Classic Capital Appreciation	20.60
Flag Investors Value Builder A	20.60	SunAmerica Balanced Assets B	16.30
Franklin Rising Dividends A	17.50	TIP Turner Growth Equity	23.80
Galaxy Equity Income A	18.40	T. Rowe Price Equity Income	20.70
Guardian Park Avenue A	22.40	United Continental Income A	12.30
Heartland Value	12.50	Van Eck Gold A	–14.20
Janus Enterprise	23.80	Vanguard Balanced Index	16.80
J.P. Morgan US Small Company	13.00	Vanguard Utilities Income	16.60
Kemper Worldwide 2004	9.00	Victory Special Value A	11.80
Lexington Strategic Investments	–11.50	Westcore Midco Growth	15.80
MainStay Cap Appreciation B	22.40	Zweig Strategy A	10.50