

# BRIEF CONTENTS

<b>Chapter 1</b>	The Nature of Econometrics and Economic Data	1
<b>PART 1: Regression Analysis with Cross-Sectional Data</b>		<b>19</b>
<b>Chapter 2</b>	The Simple Regression Model	20
<b>Chapter 3</b>	Multiple Regression Analysis: Estimation	64
<b>Chapter 4</b>	Multiple Regression Analysis: Inference	110
<b>Chapter 5</b>	Multiple Regression Analysis: OLS Asymptotics	160
<b>Chapter 6</b>	Multiple Regression Analysis: Further Issues	178
<b>Chapter 7</b>	Multiple Regression Analysis with Qualitative Information: Binary (or Dummy) Variables	217
<b>Chapter 8</b>	Heteroskedasticity	258
<b>Chapter 9</b>	More on Specification and Data Issues	293
<b>PART 2: Regression Analysis with Time Series Data</b>		<b>331</b>
<b>Chapter 10</b>	Basic Regression Analysis with Time Series Data	332
<b>Chapter 11</b>	Further Issues in Using OLS with Time Series Data	368
<b>Chapter 12</b>	Serial Correlation and Heteroskedasticity in Time Series Regressions	398
<b>PART 3: Advanced Topics</b>		<b>431</b>
<b>Chapter 13</b>	Pooling Cross Sections Across Time: Simple Panel Data Methods	432
<b>Chapter 14</b>	Advanced Panel Data Methods	466
<b>Chapter 15</b>	Instrumental Variables Estimation and Two Stage Least Squares	490
<b>Chapter 16</b>	Simultaneous Equations Models	530
<b>Chapter 17</b>	Limited Dependent Variable Models and Sample Selection Corrections	559
<b>Chapter 18</b>	Advanced Time Series Topics	606
<b>Chapter 19</b>	Carrying Out an Empirical Project	650
<b>CHAPTER APPENDICES</b>		
<b>Appendix 2A</b>		678
<b>Appendix 3A</b>		680
<b>Appendix 5A</b>		684
<b>Appendix 6A</b>		685
<b>Appendix 13A</b>		686
<b>Appendix 14A</b>		689
<b>Appendix 15A</b>		692
<b>Appendix 17A</b>		694
<b>Appendix 17B</b>		695

**APPENDICES**

---

<b>Appendix A</b>	Basic Mathematical Tools	697
<b>Appendix B</b>	Fundamentals of Probability	716
<b>Appendix C</b>	Fundamentals of Mathematical Statistics	749
<b>Appendix D</b>	Summary of Matrix Algebra	790
<b>Appendix E</b>	The Linear Regression Model in Matrix Form	801
<b>Appendix F</b>	Answers to Chapter Questions	815
<b>Appendix G</b>	Statistical Tables	825
<b>References</b>		<b>832</b>
<b>Glossary</b>		<b>838</b>
<b>Index</b>		<b>856</b>

# CONTENTS

Preface xvii  
About the Author xxvii

## CHAPTER 1 The Nature of Econometrics and Economic Data 1

---

- 1.1 What Is Econometrics? 1
  - 1.2 Steps in Empirical Economic Analysis 2
  - 1.3 The Structure of Economic Data 5
    - Cross-Sectional Data* 5
    - Time Series Data* 8
    - Pooled Cross Sections* 9
    - Panel or Longitudinal Data* 10
    - A Comment on Data Structures* 11
  - 1.4 Causality and the Notion of *Ceteris Paribus* in Econometric Analysis 12
- Summary 16  
Key Terms 17  
Problems 17  
Computer Exercises 17

### PART 1

## Regression Analysis with Cross-Sectional Data 19

### CHAPTER 2 The Simple Regression Model 20

---

- 2.1 Definition of the Simple Regression Model 20
- 2.2 Deriving the Ordinary Least Squares Estimates 25
  - A Note on Terminology* 32

- 2.3 Properties of OLS on Any Sample of Data 33
    - Fitted Values and Residuals* 33
    - Algebraic Properties of OLS Statistics* 34
    - Goodness-of-Fit* 36
  - 2.4 Units of Measurement and Functional Form 37
    - The Effects of Changing Units of Measurement on OLS Statistics* 38
    - Incorporating Nonlinearities in Simple Regression* 39
    - The Meaning of "Linear" Regression* 42
  - 2.5 Expected Values and Variances of the OLS Estimators 43
    - Unbiasedness of OLS* 43
    - Variances of the OLS Estimators* 48
    - Estimating the Error Variance* 52
  - 2.6 Regression through the Origin and Regression on a Constant 55
- Summary 56  
Key Terms 57  
Problems 58  
Computer Exercises 61

### CHAPTER 3 Multiple Regression Analysis: Estimation 64

---

- 3.1 Motivation for Multiple Regression 65
  - The Model with Two Independent Variables* 65
  - The Model with  $k$  Independent Variables* 67
- 3.2 Mechanics and Interpretation of Ordinary Least Squares 68
  - Obtaining the OLS Estimates* 68
  - Interpreting the OLS Regression Equation* 70
  - On the Meaning of "Holding Other Factors Fixed" in Multiple Regression* 72
  - Changing More Than One Independent Variable Simultaneously* 73

- OLS Fitted Values and Residuals* 73  
*A "Partialling Out" Interpretation of Multiple Regression* 74  
*Comparison of Simple and Multiple Regression Estimates* 74  
*Goodness-of-Fit* 76  
*Regression through the Origin* 77
- 3.3 The Expected Value of the OLS Estimators 79  
*Including Irrelevant Variables in a Regression Model* 84  
*Omitted Variable Bias: The Simple Case* 84  
*Omitted Variable Bias: More General Cases* 87
- 3.4 The Variance of the OLS Estimators 89  
*The Components of the OLS Variances: Multicollinearity* 90  
*Variances in Misspecified Models* 94  
*Estimating  $\sigma^2$ : Standard Errors of the OLS Estimators* 95
- 3.5 Efficiency of OLS: The Gauss-Markov Theorem 97
- 3.6 Some Comments on the Language of Multiple Regression Analysis 99
- Summary 100  
 Key Terms 101  
 Problems 102  
 Computer Exercises 106

## **CHAPTER 4 Multiple Regression Analysis: Inference 110**

---

- 4.1 Sampling Distributions of the OLS Estimators 110
- 4.2 Testing Hypotheses about a Single Population Parameter: The *t* Test 113  
*Testing against One-Sided Alternatives* 115  
*Two-Sided Alternatives* 120  
*Testing Other Hypotheses about  $\beta_j$*  122  
*Computing p-Values for t Tests* 125  
*A Reminder on the Language of Classical Hypothesis Testing* 127  
*Economic, or Practical, versus Statistical Significance* 127
- 4.3 Confidence Intervals 130
- 4.4 Testing Hypotheses about a Single Linear Combination of the Parameters 132

- 4.5 Testing Multiple Linear Restrictions:  
 The *F* Test 135  
*Testing Exclusion Restrictions* 135  
*Relationship between F and t Statistics* 141  
*The R-Squared Form of the F Statistic* 142  
*Computing p-Values for F Tests* 143  
*The F Statistic for Overall Significance of a Regression* 144  
*Testing General Linear Restrictions* 145
- 4.6 Reporting Regression Results 146  
 Summary 149  
 Key Terms 151  
 Problems 151  
 Computer Exercises 156

## **CHAPTER 5 Multiple Regression Analysis: OLS Asymptotics 160**

---

- 5.1 Consistency 161  
*Deriving the Inconsistency in OLS* 164
- 5.2 Asymptotic Normality and Large Sample Inference 165  
*Other Large Sample Tests: The Lagrange Multiplier Statistic* 170
- 5.3 Asymptotic Efficiency of OLS 173  
 Summary 174  
 Key Terms 175  
 Problems 175  
 Computer Exercises 175

## **CHAPTER 6 Multiple Regression Analysis: Further Issues 178**

---

- 6.1 Effects of Data Scaling on OLS Statistics 178  
*Beta Coefficients* 181
- 6.2 More on Functional Form 183  
*More on Using Logarithmic Functional Forms* 183  
*Models with Quadratics* 186  
*Models with Interaction Terms* 190
- 6.3 More on Goodness-of-Fit and Selection of Regressors 192  
*Adjusted R-Squared* 194  
*Using Adjusted R-Squared to Choose between Nonnested Models* 195

*Controlling for Too Many Factors in Regression Analysis* 197

*Adding Regressors to Reduce the Error Variance* 198

- 6.4 Prediction and Residual Analysis** 199  
*Confidence Intervals for Predictions* 199  
*Residual Analysis* 203  
*Predicting  $y$  When  $\log(y)$  Is the Dependent Variable* 204

Summary 208

Key Terms 209

Problems 210

Computer Exercises 212

## **CHAPTER 7 Multiple Regression Analysis with Qualitative Information: Binary (or Dummy) Variables** 217

---

7.1 Describing Qualitative Information 217

7.2 A Single Dummy Independent Variable 218  
*Interpreting Coefficients on Dummy Explanatory Variables When the Dependent Variable Is  $\log(y)$*  223

7.3 Using Dummy Variables for Multiple Categories 225  
*Incorporating Ordinal Information by Using Dummy Variables* 227

7.4 Interactions Involving Dummy Variables 230  
*Interactions among Dummy Variables* 230  
*Allowing for Different Slopes* 231  
*Testing for Differences in Regression Functions across Groups* 235

7.5 A Binary Dependent Variable: The Linear Probability Model 238

7.6 More on Policy Analysis and Program Evaluation 243

7.7 Interpreting Regression Results with Discrete Dependent Variables 246

Summary 247

Key Terms 248

Problems 248

Computer Exercises 251

## **CHAPTER 8 Heteroskedasticity** 258

---

8.1 Consequences of Heteroskedasticity for OLS 258

8.2 Heteroskedasticity-Robust Inference after OLS Estimation 259  
*Computing Heteroskedasticity-Robust LM Tests* 264

8.3 Testing for Heteroskedasticity 265  
*The White Test for Heteroskedasticity* 269

8.4 Weighted Least Squares Estimation 270  
*The Heteroskedasticity Is Known up to a Multiplicative Constant* 271  
*The Heteroskedasticity Function Must Be Estimated: Feasible GLS* 276  
*What If the Assumed Heteroskedasticity Function Is Wrong?* 280  
*Prediction and Prediction Intervals with Heteroskedasticity* 282

8.5 The Linear Probability Model Revisited 284  
 Summary 286

Key Terms 287

Problems 287

Computer Exercises 289

## **CHAPTER 9 More on Specification and Data Issues** 293

---

9.1 Functional Form Misspecification 294  
*RESET as a General Test for Functional Form Misspecification* 296  
*Tests against Nonnested Alternatives* 297

9.2 Using Proxy Variables for Unobserved Explanatory Variables 298  
*Using Lagged Dependent Variables as Proxy Variables* 303  
*A Different Slant on Multiple Regression* 304

9.3 Models with Random Slopes 305

9.4 Properties of OLS under Measurement Error 307  
*Measurement Error in the Dependent Variable* 308  
*Measurement Error in an Explanatory Variable* 310

9.5 Missing Data, Nonrandom Samples, and Outlying Observations 314

- Missing Data* 314
- Nonrandom Samples* 314
- Outliers and Influential Observations* 316

- 9.6 Least Absolute Deviations Estimation 321
- Summary 324
- Key Terms 325
- Problems 325
- Computer Exercises 327

## PART 2

### Regression Analysis with Time Series Data 331

#### CHAPTER 10 Basic Regression Analysis with Time Series Data 332

- 10.1 The Nature of Time Series Data 332
- 10.2 Examples of Time Series Regression Models 333
  - Static Models* 334
  - Finite Distributed Lag Models* 334
  - A Convention about the Time Index* 337
- 10.3 Finite Sample Properties of OLS under Classical Assumptions 337
  - Unbiasedness of OLS* 337
  - The Variances of the OLS Estimators and the Gauss-Markov Theorem* 340
  - Inference under the Classical Linear Model Assumptions* 343
- 10.4 Functional Form, Dummy Variables, and Index Numbers 344
- 10.5 Trends and Seasonality 351
  - Characterizing Trending Time Series* 351
  - Using Trending Variables in Regression Analysis* 354
  - A Detrending Interpretation of Regressions with a Time Trend* 356
  - Computing R-Squared when the Dependent Variable Is Trending* 358
  - Seasonality* 359
- Summary 361
- Key Terms 362
- Problems 363
- Computer Exercises 364

#### CHAPTER 11 Further Issues in Using OLS with Time Series Data 368

- 11.1 Stationary and Weakly Dependent Time Series 369
  - Stationary and Nonstationary Time Series* 369
  - Weakly Dependent Time Series* 370
- 11.2 Asymptotic Properties of OLS 372
- 11.3 Using Highly Persistent Time Series in Regression Analysis 379
  - Highly Persistent Time Series* 379
  - Transformations on Highly Persistent Time Series* 383
  - Deciding Whether a Time Series Is  $I(1)$*  384
- 11.4 Dynamically Complete Models and the Absence of Serial Correlation 387
- 11.5 The Homoskedasticity Assumption for Time Series Models 390
- Summary 390
- Key Terms 392
- Problems 392
- Computer Exercises 394

#### CHAPTER 12 Serial Correlation and Heteroskedasticity in Time Series Regressions 398

- 12.1 Properties of OLS with Serially Correlated Errors 398
  - Unbiasedness and Consistency* 398
  - Efficiency and Inference* 399
  - Goodness-of-Fit* 400
  - Serial Correlation in the Presence of Lagged Dependent Variables* 401
- 12.2 Testing for Serial Correlation 402
  - A t Test for  $AR(1)$  Serial Correlation with Strictly Exogenous Regressors* 402
  - The Durbin-Watson Test under Classical Assumptions* 404
  - Testing for  $AR(1)$  Serial Correlation without Strictly Exogenous Regressors* 406
  - Testing for Higher Order Serial Correlation* 407
- 12.3 Correcting for Serial Correlation with Strictly Exogenous Regressors 409
  - Obtaining the Best Linear Unbiased Estimator in the  $AR(1)$  Model* 409

*Feasible GLS Estimation with AR(1) Errors* 411  
*Comparing OLS and FGLS* 413  
*Correcting for Higher Order Serial Correlation* 414

- 12.4** Differencing and Serial Correlation 415  
**12.5** Serial Correlation-Robust Inference after OLS 417  
**12.6** Heteroskedasticity in Time Series Regressions 420  
*Heteroskedasticity-Robust Statistics* 421  
*Testing for Heteroskedasticity* 421  
*Autoregressive Conditional Heteroskedasticity* 422  
*Heteroskedasticity and Serial Correlation in Regression Models* 424
- Summary 425  
 Key Terms 426  
 Problems 426  
 Computer Exercises 427

## PART 3

### Advanced Topics 431

#### CHAPTER 13 Pooling Cross Sections across Time: Simple Panel Data Methods 432

- 13.1** Pooling Independent Cross Sections across Time 433  
*The Chow Test for Structural Change across Time* 437
- 13.2** Policy Analysis with Pooled Cross Sections 438
- 13.3** Two-Period Panel Data Analysis 443  
*Organizing Panel Data* 449
- 13.4** Policy Analysis with Two-Period Panel Data 449
- 13.5** Differencing with More Than Two Time Periods 452  
*Potential Pitfalls in First Differencing Panel Data* 457
- Summary 458  
 Key Terms 458  
 Problems 458  
 Computer Exercises 460

#### CHAPTER 14 Advanced Panel Data Methods 466

- 14.1** Fixed Effects Estimation 466  
*The Dummy Variable Regression* 470  
*Fixed Effects or First Differencing?* 471  
*Fixed Effects with Unbalanced Panels* 473
- 14.2** Random Effects Models 474  
*Random Effects or Fixed Effects?* 477
- 14.3** The Correlated Random Effects Approach 479
- 14.4** Applying Panel Data Methods to Other Data Structures 481
- Summary 483  
 Key Terms 484  
 Problems 484  
 Computer Exercises 485

#### CHAPTER 15 Instrumental Variables Estimation and Two Stage Least Squares 490

- 15.1** Motivation: Omitted Variables in a Simple Regression Model 491  
*Statistical Inference with the IV Estimator* 495  
*Properties of IV with a Poor Instrumental Variable* 499  
*Computing R-Squared after IV Estimation* 501
- 15.2** IV Estimation of the Multiple Regression Model 502
- 15.3** Two Stage Least Squares 506  
*A Single Endogenous Explanatory Variable* 506  
*Multicollinearity and 2SLS* 508  
*Multiple Endogenous Explanatory Variables* 509  
*Testing Multiple Hypotheses after 2SLS Estimation* 510
- 15.4** IV Solutions to Errors-in-Variables Problems 510
- 15.5** Testing for Endogeneity and Testing Overidentifying Restrictions 512

*Testing for Endogeneity* 512  
*Testing Overidentification Restrictions* 513

- 15.6 2SLS with Heteroskedasticity 516  
 15.7 Applying 2SLS to Time Series Equations 516  
 15.8 Applying 2SLS to Pooled Cross Sections and Panel Data 518  
 Summary 520  
 Key Terms 521  
 Problems 521  
 Computer Exercises 524

## CHAPTER 16 Simultaneous Equations Models 530

---

- 16.1 The Nature of Simultaneous Equations Models 531  
 16.2 Simultaneity Bias in OLS 534  
 16.3 Identifying and Estimating a Structural Equation 536  
*Identification in a Two-Equation System* 536  
*Estimation by 2SLS* 541  
 16.4 Systems with More Than Two Equations 543  
*Identification in Systems with Three or More Equations* 543  
*Estimation* 544  
 16.5 Simultaneous Equations Models with Time Series 544  
 16.6 Simultaneous Equations Models with Panel Data 548  
 Summary 550  
 Key Terms 551  
 Problems 551  
 Computer Exercises 554

## CHAPTER 17 Limited Dependent Variable Models and Sample Selection Corrections 559

---

- 17.1 Logit and Probit Models for Binary Response 560  
*Specifying Logit and Probit Models* 560

*Maximum Likelihood Estimation of Logit and Probit Models* 563  
*Testing Multiple Hypotheses* 564  
*Interpreting the Logit and Probit Estimates* 565

- 17.2 The Tobit Model for Corner Solution Responses 572  
*Interpreting the Tobit Estimates* 574  
*Specification Issues in Tobit Models* 579  
 17.3 The Poisson Regression Model 580  
 17.4 Censored and Truncated Regression Models 585  
*Censored Regression Models* 585  
*Truncated Regression Models* 589  
 17.5 Sample Selection Corrections 591  
*When Is OLS on the Selected Sample Consistent?* 591  
*Incidental Truncation* 593  
 Summary 597  
 Key Terms 598  
 Problems 598  
 Computer Exercises 600

## CHAPTER 18 Advanced Time Series Topics 606

---

- 18.1 Infinite Distributed Lag Models 607  
*The Geometric (or Koyck)*  
*Distributed Lag* 609  
*Rational Distributed Lag Models* 611  
 18.2 Testing for Unit Roots 613  
 18.3 Spurious Regression 618  
 18.4 Cointegration and Error Correction Models 620  
*Cointegration* 620  
*Error Correction Models* 625  
 18.5 Forecasting 626  
*Types of Regression Models Used for Forecasting* 628  
*One-Step-Ahead Forecasting* 629  
*Comparing One-Step-Ahead Forecasts* 632  
*Multiple-Step-Ahead Forecasts* 634  
*Forecasting Trending, Seasonal, and Integrated Processes* 636



- Summary** 641  
**Key Terms** 643  
**Problems** 643  
**Computer Exercises** 645

## **CHAPTER 19 Carrying Out an Empirical Project 650**

---

- 19.1 Posing a Question 650  
 19.2 Literature Review 652  
 19.3 Data Collection 653  
     *Deciding on the Appropriate Data Set* 653  
     *Entering and Storing Your Data* 654  
     *Inspecting, Cleaning, and Summarizing Your Data* 656  
 19.4 Econometric Analysis 657  
 19.5 Writing an Empirical Paper 660  
     *Introduction* 660  
     *Conceptual (or Theoretical) Framework* 661  
     *Econometric Models and Estimation Methods* 661  
     *The Data* 664  
     *Results* 664  
     *Conclusions* 665  
     *Style Hints* 666  
 Summary 668  
 Key Terms 668  
 Sample Empirical Projects 668  
 List of Journals 674  
 Data Sources 675

## **CHAPTER APPENDICES**

---

- Appendix 2A 678  
 Appendix 3A 680  
 Appendix 5A 684  
 Appendix 6A 685  
 Appendix 13A 686  
 Appendix 14A 689  
 Appendix 15A 692  
 Appendix 17A 694  
 Appendix 17B 695

## **APPENDIX A Basic Mathematical Tools 697**

---

- A.1** The Summation Operator and Descriptive Statistics 697  
**A.2** Properties of Linear Functions 699  
**A.3** Proportions and Percentages 701  
**A.4** Some Special Functions and Their Properties 704  
     *Quadratic Functions* 704  
     *The Natural Logarithm* 706  
     *The Exponential Function* 710  
**A.5** Differential Calculus 711  
 Summary 713  
 Key Terms 713  
 Problems 713

## **APPENDIX B Fundamentals of Probability 716**

---

- B.1** Random Variables and Their Probability Distributions 716  
     *Discrete Random Variables* 717  
     *Continuous Random Variables* 719  
**B.2** Joint Distributions, Conditional Distributions, and Independence 721  
     *Joint Distributions and Independence* 721  
     *Conditional Distributions* 723  
**B.3** Features of Probability Distributions 724  
     *A Measure of Central Tendency: The Expected Value* 724  
     *Properties of Expected Values* 725  
     *Another Measure of Central Tendency: The Median* 727  
     *Measures of Variability: Variance and Standard Deviation* 728  
     *Variance* 728  
     *Standard Deviation* 730  
     *Standardizing a Random Variable* 730  
     *Skewness and Kurtosis* 731  
**B.4** Features of Joint and Conditional Distributions 731

<b>Measures of Association: Covariance and Correlation</b>	731
<b>Covariance</b>	731
<b>Correlation Coefficient</b>	733
<b>Variance of Sums of Random Variables</b>	734
<b>Conditional Expectation</b>	735
<b>Properties of Conditional Expectation</b>	736
<b>Conditional Variance</b>	738
<b>B.5 The Normal and Related Distributions</b>	739
<b>The Normal Distribution</b>	739
<b>The Standard Normal Distribution</b>	740
<b>Additional Properties of the Normal Distribution</b>	742
<b>The Chi-Square Distribution</b>	743
<b>The t Distribution</b>	743
<b>The F Distribution</b>	744
<b>Summary</b>	746
<b>Key Terms</b>	746
<b>Problems</b>	746

## APPENDIX C Fundamentals of Mathematical Statistics 749

---

<b>C.1 Populations, Parameters, and Random Sampling</b>	749
<b>Sampling</b>	750
<b>C.2 Finite Sample Properties of Estimators</b>	750
<b>Estimators and Estimates</b>	751
<b>Unbiasedness</b>	752
<b>The Sampling Variance of Estimators</b>	754
<b>Efficiency</b>	756
<b>C.3 Asymptotic or Large Sample Properties of Estimators</b>	757
<b>Consistency</b>	757
<b>Asymptotic Normality</b>	760
<b>C.4 General Approaches to Parameter Estimation</b>	762
<b>Method of Moments</b>	762
<b>Maximum Likelihood</b>	763
<b>Least Squares</b>	764
<b>C.5 Interval Estimation and Confidence Intervals</b>	764

<b>The Nature of Interval Estimation</b>	764
<b>Confidence Intervals for the Mean from a Normally Distributed Population</b>	766
<b>A Simple Rule of Thumb for a 95% Confidence Interval</b>	769
<b>Asymptotic Confidence Intervals for Nonnormal Populations</b>	770
<b>C.6 Hypothesis Testing</b>	771
<b>Fundamentals of Hypothesis Testing</b>	772
<b>Testing Hypotheses about the Mean in a Normal Population</b>	774
<b>Asymptotic Tests for Nonnormal Populations</b>	777
<b>Computing and Using p-Values</b>	778
<b>The Relationship between Confidence Intervals and Hypothesis Testing</b>	781
<b>Practical versus Statistical Significance</b>	782
<b>C.7 Remarks on Notation</b>	783
<b>Summary</b>	784
<b>Key Terms</b>	784
<b>Problems</b>	785

## APPENDIX D Summary of Matrix Algebra 790

---

<b>D.1 Basic Definitions</b>	790
<b>D.2 Matrix Operations</b>	791
<b>Matrix Addition</b>	791
<b>Scalar Multiplication</b>	792
<b>Matrix Multiplication</b>	792
<b>Transpose</b>	793
<b>Partitioned Matrix Multiplication</b>	794
<b>Trace</b>	794
<b>Inverse</b>	795
<b>D.3 Linear Independence and Rank of a Matrix</b>	795
<b>D.4 Quadratic Forms and Positive Definite Matrices</b>	796
<b>D.5 Idempotent Matrices</b>	796
<b>D.6 Differentiation of Linear and Quadratic Forms</b>	797
<b>D.7 Moments and Distributions of Random Vectors</b>	797

<i>Expected Value</i>	797
<i>Variance-Covariance Matrix</i>	797
<i>Multivariate Normal Distribution</i>	798
<i>Chi-Square Distribution</i>	798
<i>t Distribution</i>	799
<i>F Distribution</i>	799

Summary	799
Key Terms	799
Problems	800

## **APPENDIX E The Linear Regression Model in Matrix Form 801**

---

E.1 The Model and Ordinary Least Squares Estimation	801
E.2 Finite Sample Properties of OLS	803
E.3 Statistical Inference	807

E.4 Some Asymptotic Analysis	809
<i>Wald Statistics for Testing Multiple Hypotheses</i>	812
Summary	813
Key Terms	813
Problems	813

## **APPENDIX F Answers to Chapter Questions 815**

---

## **APPENDIX G Statistical Tables 825**

---

References	832
Glossary	838
Index	856