
CONTENTS

1	Introduction	1
1-1	Randomized Experiments	1
1-2	Randomized Experiments in the Social Sciences	6
1-3	Regression	8
1-4	Brief Outline of the Book	11
2	Simple Regression	13
2-1	An Example	13
2-2	Possible Criteria for Fitting a Line	15
2-3	The Least Squares Solution	18
2-4	The Mathematical Regression Model	25
2-5	The Mean and Variance of $\hat{\alpha}$ and $\hat{\beta}$	29
2-6	The Gauss-Markov Theorem	31
2-7	The Distribution of $\hat{\beta}$	33
2-8	Confidence Intervals and Tests for β	35
2-9	Interpolation	42
2-10	Dangers of Extrapolation	48
2-11	Least Squares When X Is Random	49
2-12	Maximum Likelihood Estimation (MLE)	50
	Appendices	
2-A	Linear Transformations	59
2-B	Desirable Properties of Estimators	59
2-C	Proof of the Gauss-Markov Theorem	71
2-D	Maximum Likelihood Estimate of σ^2	73

3 Multiple Regression	75
3-1 Introduction	75
3-2 The Mathematical Model	77
3-3 Least Squares (Maximum Likelihood) Estimation	79
3-4 Multicollinearity	84
3-5 Confidence Intervals and Statistical Tests	88
3-6 How Many Regressors Should Be Retained?	92
3-7 Prob-Value	94
3-8 Simple and Multiple Regression Compared	99
4 Multiple Regression Extensions	104
4-1 Dummy (0-1) Variables	104
4-2 Analysis of Variance (ANOVA)	115
4-3 Simplest Nonlinear Regression	120
4-4 Nonlinearities Requiring a Transformation	124
4-5 Logits to Refine a 0-1 Response	135
4-6 Intractable Nonlinearity	138
4-7 The Physical and Social Sciences Contrasted	
Appendices	140
4-A MLE for the Logit Model	147
4-B Intractable Nonlinear Regressions Solved by Successive Linear Approximation	148
5 Correlation	152
5-1 Simple Correlation	152
5-2 Correlation and Regression	163
5-3 Partial and Multiple Correlation	179
5-4 Path Analysis	194
6 Time Series	208
A Changing Variance in the Error	208
6-1 Heteroscedasticity	208
B Simple Time Series Decomposition and Forecasting	213
6-2 The Components of a Time Series	213
6-3 Trend	214
6-4 Seasonal	215
6-5 Random Tracking (Autocorrelated) Error	220
6-6 Forecasting	222

C	Serially Correlated Error and Lagged Variables	226
6-7	Serial Correlation in the Error	226
6-8	Lagged X Variables	238
6-9	Serial Correlation in the Dependent Variable	244
6-10	Serial Correlation in Both the Error and the Dependent Variable	245
D	Box Jenkins Methods	248
6-11	ARIMA Models	248
6-12	Estimation and Forecasting	260
E	Spectral Analysis	265
6-13	Cycles	265
6-14	Spectral Analysis	268
6-15	Cross-Spectral Analysis	274
7	Simultaneous Equations, and Other Examples of Correlated Regressor and Error	278
7-1	A New Look at OLS	278
7-2	Inconsistency of OLS When e and X Correlated	281
7-3	IV Extended to Multiple Regression	283
7-4	Simultaneous Equations—The Consumption Function	284
7-5	Errors in Both Variables	293
8	The Identification Problem	301
8-1	Unidentified Equations	301
8-2	Identification Using Prior Information	304
8-3	Identification Using Prior Information About Exogenous Variables	307
8-4	Requirement for Identification, In General	309
8-5	Overidentification	314
8-6	Summary: Identification in Context	317
9	Selected Estimating Techniques	319
9-1	Two-Stage Least Squares (2SLS)	319
9-2	Other Procedures	321
9-3	Recursive Systems	323

10 Bayesian Inference	327
10-1 Posterior Probabilities in General	327
10-2 Population Proportion π	332
10-3 Mean μ of a Normal Population	339
10-4 Bayesian Regression	347
11 Analysis of Variance (ANOVA)	352
11-1 One-Factor ANOVA	352
11-2 Two-Factor ANOVA, without Interaction	369
11-3 Two-Factor ANOVA, with Interaction	376
11-4 Random Effects Models	394
11-5 Bayes Adjustments to ANOVA	399
11-6 Bayes Adjustment for Simple Regression	407
Appendices	
11-A Proof of the Bayes ANOVA Estimate	409
11-B Proof of the Bayes Regression Estimate	411
 REGRESSION USING MATRICES	 413
Introduction	415
12 Multiple Regression Using Matrices	417
12-1 Introduction to the General Linear Model	417
12-2 Least Squares Estimation (OLS)	420
12-3 Maximum Likelihood Estimation (MLE)	421
12-4 Distribution of $\hat{\beta}$	424
12-5 Confidence Regions and Hypothesis Testing	426
12-6 Multicollinearity	438
12-7 Interpolation and Prediction	442
Appendix	
12-A Partial Derivatives of Linear and Quadratic Forms	447
 13 Distribution Theory: How the Normal, t, χ^2, and F Distributions Are Related	 449
13-1 Introduction	449
13-2 χ^2 , The Chi-Square Distribution	449
13-3 t Distribution	456

13-4	The F Distribution	459
13-5	Comparison and Review	461
14	Vector Geometry	464
14-1	The Geometric Interpretation of Vectors	464
14-2	Least Squares Fit	479
14-3	Orthogonal Regressors	482
14-4	ANOVA for Simple Regression	483
14-5	The Statistical Model	484
14-6	Multicollinearity	486
14-7	Correlation and $\cos \theta$	487
14-8	Correlations—Simple, Multiple, and Partial	488
14-9	Tests When There are k Regressors	491
14-10	Forward Stepwise Regression	495
15	Other Regression Topics	501
15-1	Specification Error	501
15-2	Principal Components	507
	Appendix Tables	515
	Answers to Odd-Numbered Problems	535
	Bibliography	545
	Index	549