

BRIEF CONTENTS

1. Introducing SAS	1
2. The Simple Linear Regression Model	50
3. Interval Estimation and Hypothesis Testing	82
4. Prediction, Goodness-of-Fit, and Modeling Issues	103
5. The Multiple Regression Model	130
6. Further Inference in the Multiple Regression Model	162
7. Using Indicator Variables	190
8. Heteroskedasticity	207
9. Regression with Time-Series Data: Stationary Variables	264
10. Random Regressors and Moment-Based Estimation	304
11. Simultaneous Equations Models	346
12. Regression with Time-Series Data: Nonstationary Variables	369
13. Vector Error Correction and Vector Autoregressive Models	390
14. Time-Varying Volatility and ARCH Models	406
15. Panel Data Models	428
16. Qualitative and Limited Dependent Variable Models	468
Appendix A. Math Functions	522
Appendix B. Probability	528
Appendix C. Review of Statistical Inference	541

CONTENTS

1. Introducing SAS 1

1.1	The SAS System	1
1.2	Starting SAS	1
1.3	The opening display	1
1.4	Exiting SAS	3
1.5	Using Principles of Econometrics, 4E data files	3
	1.5.1 Data definition files	4
1.6	A working environment	4
1.7	SAS Program structure	6
	1.7.1 SAS comment statements	6
	1.7.2 Creating a SAS program	7
	1.7.3 Saving a SAS program	8
	1.7.4 Running a SAS program	9
	1.7.5 Printing data with PROC PRINT	10
	1.7.6 Saving SAS output	12
	1.7.7 Opening SAS programs	15
1.8	Summary Statistics using PROC MEANS	15
1.9	Making errors in SAS programs	17
	1.9.1 Typing errors	18
	1.9.2 The SAS semi-colon “;”	18
1.10	SAS Graphics: A scatter diagram	19
	1.10.1 PROC PLOT	19
	1.10.2 PROC GPLOT	20
1.11	Creating or modifying data sets	22
	1.11.1 The SET statement	22
	1.11.2 Using DROP and KEEP	22
1.12	Creating new variables	23
	1.12.1 Arithmetic operators	23
	1.12.2 Comparison operators	24
	1.12.3 Logical operators	25
	1.12.4 Using SAS functions	25
	1.12.5 Missing values	26
	1.12.6 Using IF-THEN to recode variables	26
	1.12.7 Creating a data subset	27
	1.12.8 Using SET to combine data sets	27
1.13	Using SET to open SAS data sets	28
	1.13.1 Using SAS system options	29

	1.13.2 Adding labels	30
1.14	Using PROC SORT	31
	1.14.1 PROC PRINT with BY	31
	1.14.2 PROC MEANS with BY	32
	1.14.3 PROC SORT on two variables	32
	1.14.4 Sort in descending order	33
1.15	Merging data sets	33
Appendix 1A	A guide to SAS help and online documentation	34
	1A.1 SAS command line	35
	1A.2 SAS help	35
	1A.3 SAS online documentation	37
	1A.4 SAS online examples	40
	1A.5 Other resources	40
Appendix 1B	Importing data into SAS	41
	1B.1 Reading ASCII data	41
	1B.2 Reading an external ASCII file	42
	1B.3 Importing data in Excel format	47
2. The Simple Linear Regression Model	50	
2.1	Econometric model and estimators	50
2.2	Example: the food expenditure data	52
2.3	Scatter diagram using PROC GPLOT	53
2.4	Using PROC REG for simple regression	54
	2.4.1 Analysis of variance table	54
	2.4.2 ANOVA auxiliary information	56
	2.4.3 PROC MEANS options	56
2.5	PROC REG options	57
	2.5.1 Covariance matrix	57
	2.5.2 The least squares residuals	58
	2.5.3 Output residuals	58
	2.5.4 PROC UNIVARIATE analysis of residuals	59
2.6	Prediction with PROC REG	60
	2.6.1 Deleting missing values from data set	62
	2.6.2 Plotting a fitted line using PROC GPLOT	63
2.7	Creating plots using PROC REG	63
2.8	SAS ODS graphics	64

2.9	Fitting nonlinear relationships	66	4. Prediction, Goodness-of-Fit, and Modeling Issues	103
2.10	Using indicator variables	70	4.1	Least squares prediction theory 103
Appendix 2A	Calculation of least squares estimates: Details	71	4.2	Least squares prediction example 104
Appendix 2B	Monte Carlo simulation	75	4.3	Measuring goodness-of-fit 108
2B.1	The true estimator variance	76	4.4	Residual analysis 109
2B.2	Regression on artificial data	77	4.4.1	Using PROC AUTOREG 112
2B.3	OUTEST from PROC REG	78	4.5	SAS ODS graphics 113
2B.4	Simulating samples using do-loops	79	4.5.1	The SAS Image Editor 114
2B.5	Summarizing parameter estimates	79	4.5.2	ODS plots 115
3. Interval Estimation and Hypothesis Testing			4.6	Nonlinear relationships 118
82			4.7	Log-linear models 122
3.1	Interval estimation	82	4.7.1	A growth model 122
3.1.1	Interval estimation details	84	4.7.2	A wage equation 124
3.2	Hypothesis testing theory	85	4.7.3	Prediction in the log-linear model 127
3.2.1	Right tail t-tests	86		
3.2.2	Left tail t-tests	86		
3.2.3	Two-tail t-tests	86		
3.2.4	The p-value for t-tests	87		
3.3	Hypothesis testing examples	87	5. The Multiple Regression Model	130
3.3.1	Right tail test of significance	87	5.1	Multiple regression theory and methods 130
3.3.2	Right tail test for an economic hypothesis	88	5.2	Multiple regression example 132
3.3.3	Left tail test of an economic hypothesis	89	5.2.1	Using PROC REG 133
3.3.4	Two tail test of an economic hypothesis	90	5.2.2	Using PROC AUTOREG 136
3.3.5	Two tail test of significance	91	5.2.3	Using PROC MODEL 136
3.4	Testing and estimating linear combinations	91	5.3	Polynomial models 137
3.4.1	PROC MODEL	92	5.3.1	Using PROC REG 138
Appendix 3A	Monte Carlo simulation	94	5.3.2	Using PROC MODEL 138
3A.1	Summarizing interval estimates	94	5.4	Log-linear models 139
3A.2	Summarizing t-tests	96	5.4.1	Using PROC REG 140
3A.3	Illustrating the central limit theorem	97	5.4.2	Using PROC MODEL 141
3A.4	Monte Carlo experiment with triangular errors	99	Appendix 5A	The delta method in PROC MODEL 142
			5A.1	Monte Carlo study of delta method 143
			Appendix 5B	Matrix operations 147
			5B.1	Vector concepts 148
			5B.2	Matrix concepts 149
			Appendix 5C	Regression calculations in matrix notation 154
			5C.1	SAS/IML module for multiple regression 155
			5C.2	Estimating a linear combination of parameters 158

5C.3	Testing a single linear hypothesis	158	7.5	Differences-in-differences estimation	202
5C.4	Illustrating computations	159			
5C.5	Delta method	160			
6. Further Inference in the Multiple Regression Model 162					
6.1	Joint hypothesis tests	162	8.1	The nature of heteroskedasticity	207
6.1.1	An example	163	8.2	Plotting the least squares residuals	207
6.1.2	PROC REG Test statement	165	8.3	Least squares with robust standard errors	209
6.1.3	F-test of model significance	167	8.4	Generalized least squares estimation	211
6.1.4	Testing in PROC AUTOREG	167	8.4.1	Applying GLS using transformed data	212
6.1.5	PROC AUTOREG fit statistics	168	8.4.2	Using PROC REG with a WEIGHT statement	213
6.1.6	Testing in PROC MODEL	169	8.5	Estimating the variance function	213
6.2	Restricted estimation	170	8.5.1	Model of multiplicative heteroskedasticity	213
6.3	Model specification issues	172	8.5.2	A convenient special case	214
6.3.1	The RESET test	174	8.5.3	Two-step estimator for multiplicative heteroskedasticity	214
6.4	Collinearity	175	8.6	Lagrange multiplier (LM) test for heteroskedasticity	216
6.4.1	Consequences of collinearity	176	8.7	Goldfeld-Quandt test for heteroskedasticity	218
6.4.2	Diagnosing collinearity	176	8.8	A heteroskedastic partition	221
6.4.3	Condition indexes	178	8.8.1	The Goldfeld-Quandt test	222
6.5	Prediction in multiple regression	179	8.8.2	Generalized least squares estimation	224
Appendix 6A	Extending the matrix approach	180	8.9	Using PROC AUTOREG for heteroskedasticity	225
6A.1	ANOVA for OLS module	180	8.9.1	PROC AUTOREG for a heteroskedastic partition	226
6A.2	Prediction and prediction interval	183	8.9.2	An extended heteroskedasticity model	227
6A.3	Tests of a joint hypothesis	184	8.10	Using SAS ODS graphics	228
6A.4	Collinearity diagnostics	187	8.11	Using PROC MODEL for heteroskedastic data	229
7. Using Indicator Variables 190					
7.1	Indicator variables	190	Appendix 8A	Monte Carlo simulations	231
7.1.1	Slope and intercept effects	190	8A.1	Simulating heteroskedastic data	231
7.1.2	The Chow test	192	8A.2	Heteroskedastic data Monte Carlo experiment	233
7.2	Using PROC MODEL for log-linear regression	195	8A.3	Using PROC IML to compute true variances	238
7.3	The linear probability model	197			
7.4	Treatment effects	198			

	8A.4	White HCE Monte Carlo experiment 242	9.5.1	Least squares and HAC standard errors 277
Appendix 8B		Two-step estimation 245	9.5.2	Nonlinear least squares 278
	8B.1	Simulating heteroskedastic data 245	9.5.3	Estimating a more general model 280
	8B.2	Feasible GLS in multiplicative model 246	9.6	Autoregressive distributed lag models 282
	8B.3	Feasible GLS in PROC IML 247	9.6.1	The Phillips curve 282
Appendix 8C		Multiplicative model Monte Carlo 249	9.6.2	Okun's law 284
	8C.1	Simulating heteroskedastic data 249	9.6.3	Autoregressive models 285
	8C.2	The least squares estimator 250	9.7	Forecasting 285
	8C.3	Maximum likelihood estimation 251	9.7.1	Forecasting with an AR model 286
Appendix 8D		Multiplicative model MLE 253	9.7.2	Exponential smoothing 287
	8D.1	Using PROC AUTOREG 253	9.8	Multiplier analysis 289
	8D.2	Numerical optimization in the multiplicative model 254	Appendix 9A	Estimation and forecasting with PROC ARIMA 291
	8D.3	MLE based tests for heteroskedasticity 257	9A.1	Finite distributed lag models in PROC ARIMA 291
	8D.4	MLE using analytic derivatives 258	9A.2	Serially correlated error models in PROC ARIMA 293
	8D.5	MLE using method of scoring 260	9A.3	Autoregressive distributed lag models in PROC ARIMA 295
			9A.4	Autoregressive models and forecasting in PROC ARIMA 297
			Appendix 9B	GLS estimation of AR(1) error model 299

Chapter 9 Regression with Time-Series Data: Stationary Variables 264

9.1	Time-series data 264
9.2	Finite distributed lags 264
	9.2.1 Lag and difference operators 265
	9.2.2 Time-series plots 267
	9.2.3 Model estimation 268
9.3	Serial correlation 269
	9.3.1 Residual correlogram 272
9.4	Testing for serially correlated errors 274
	9.4.1 A Lagrange multiplier (LM) test 274
	9.4.2 Durbin-Watson test 276
9.5	Estimation with serially correlated errors 277

10. Random Regressors and Moment-Based Estimation 304

10.1	The consequences of random regressors 304
10.2	Instrumental variables estimation 305
	10.2.1 Two-stage least squares estimation 306
10.3	An illustration using simulated data 307
	10.3.1 Using two-stage least squares 309
	10.3.2 Specification testing 310
10.4	A wage equation 315
	10.4.1 Robust specification tests 319
10.5	Using PROC MODEL 321
	10.5.1 Robust 2SLS estimation 321

10.5.2	Using the Hausman test command	321	11A.2	Fuller's modified LIML	357
Appendix 10A	Simulating endogenous regressors	323	11A.3	Advantages of LIML	358
10A.1	Simulating the data	323	11A.4	Stock-Yogo weak IV tests for LIML	358
10A.2	The Cholesky decomposition	326	11A.5	LIML and k-class algebra	358
Appendix 10B	Using PROC IML for 2SLS	328	11A.6	PROC IML for LIML and k-class	359
10B.1	The model, estimators and tests	328	Appendix 11B	Monte Carlo simulation	364
10B.2	PROC IML commands	330			
Appendix 10C	The repeated sampling properties of IV/2SLS	336			
Appendix 10D	Robust 2SLS and GMM	342			
10D.1	The model, estimators and tests	342			
10D.2	Using PROC MODEL and IML	342			
11. Simultaneous Equations Models 346					
11.1	Simultaneous equations	346	12.1	Stationary and nonstationary variables	369
11.1.1	Structural equations	346	12.1.1	The first-order autoregressive model	375
11.1.2	Reduced form equations	347	12.1.2	Random walk models	375
11.1.3	Why least squares fails	347	12.2	Spurious regressions	375
11.1.4	Two-stage least squares estimation	348	12.3	Unit root tests for stationarity	378
11.2	Truffle supply and demand	348	12.3.1	The Dickey-Fuller tests: an example	380
11.2.1	The reduced form equations	349	12.3.2	Order of integration	382
11.2.2	Two-stage least squares estimation	351	12.4	Cointegration	385
11.2.3	2SLS using PROC SYSLIN	351	12.4.1	An example of a cointegration test	386
11.3	Limited information maximum likelihood (LIML)	352	12.4.2	The error correction model	388
11.3.1	LIML modifications	353			
11.4	System estimation methods	354			
11.4.1	Three stage least squares (3SLS)	354			
11.4.2	Iterated three stage least squares	354			
11.4.3	Full information maximum likelihood (FIML)	355			
11.4.4	Postscript	356			
Appendix 11A	Alternatives to two-stage least squares	356			
11A.1	The LIML estimator	357			
12. Regression with Time-Series Data: Nonstationary Variables 369					
			13.1	VEC and VAR models	390
			13.2	Estimating a vector error correction model	391
			13.3	Estimating a VAR model	397
			13.4	Impulse responses and variance decompositions	403
13. Vector Error Correction and Vector Autoregressive Models 390					
			14.1	Time-varying volatility	406
			14.2	Testing, estimating and forecasting	411
			14.2.1	Testing for ARCH effects	412
			14.2.2	Estimating an ARCH model	415
			14.2.3	Forecasting volatility	417
			14.3	Extensions	418
14. Time-Varying Volatility and ARCH Models 406					

14.3.1	The GARCH model—generalized ARCH	418	16.1.1	The linear probability model
14.3.2	Allowing for an asymmetric effect—threshold GARCH	421	16.1.2	The probit model
14.3.3	GARCH-in-mean and time-varying risk premium	424	16.1.3	The logit model
15. Panel Data Models	428		16.1.4	A labor force participation model
15.1	A microeconometric panel	428	16.2	Probit for consumer choice
15.2	A pooled model	429	16.2.1	Wald tests
15.2.1	Cluster-robust standard errors	430	16.2.2	Likelihood ratio tests
15.3	The fixed effects model	432	16.3	Multinomial logit
15.3.1	The fixed effects estimator	435	16.3.1	Example: post-secondary education choice
15.3.2	The fixed effects estimator using PROC PANEL	438	16.4	Conditional logit
15.3.3	Fixed effects using the complete panel	439	16.4.1	Marginal effects
15.4	Random effects estimation	440	16.4.2	Testing the IIA assumption
15.4.1	The Breusch-Pagan test	442	16.5	Ordered choice models
15.4.2	The Hausman test	442	16.6	Models for count data
15.5	Sets of regression equations	444	16.7	Limited dependent variable models
15.5.1	Seemingly unrelated regressions	447	16.7.1	Censored variable models
15.5.2	Using PROC MODEL for SUR	449	16.7.2	Sample selection model
Appendix 15A	Pooled OLS robust covariance matrix	451	Appendix 16A	Probit maximum likelihood estimation
15A.1	NLS examples	452	16A.1	Probit estimation
15A.2	Using PROC IML	453	16A.2	Predicted probabilities
Appendix 15B	Panel data estimation details	454	16A.3	Marginal effects
15B.1	Estimating variance components	454	16A.4	SAS/IML code for probit
15B.2	Using PROC PANEL	456	517	
15B.3	Using PROC IML	458	Appendix A. Math Functions	522
Appendix 15C	Robust fixed effects estimation	461	A.1	SAS math and logical operators
Appendix 15D	The Hausman-Taylor estimator	464	A.2	Math functions
16. Qualitative and Limited Dependent Variable Models	468		A.3	Matrix manipulation
16.1	Models with binary dependent variables	468	Appendix B. Probability	528
			B.1	Probability calculations
			B.2	Quantiles
			B.3	Plotting probability density functions
			B.3.1	Normal distribution
			B.3.2	t-distribution
			B.3.3	Chi-square distribution
			B.3.4	F-distribution
			B.4	Random numbers

Appendix C. Review of Statistical Inference

541

- C.1 Histogram 541
- C.2 Summary statistics 542
 - C.2.1 Estimating higher moments 544
 - C.2.2 Jarque-Bera normality test 545
- C.3 Confidence interval for the mean 546
- C.4 Testing the population mean 546
 - C.4.1 A right-tail test 547
 - C.4.2 A two-tail test 547
 - C.4.3 Automatic tests using PROC TTEST 548
- C.5 Maximum likelihood estimation: one parameter 549
 - C.5.1 A coin flip example 549
 - C.5.2 Statistical inference 551
 - C.5.3 Inference in the coin flip example 553
- C.6 Maximum likelihood estimation 554
 - C.6.1 Exponential distribution example 556
 - C.6.2 Gamma distribution example 558
 - C.6.3 Testing the gamma distribution 559
- C.7 Exponential model using SAS/IML 560
 - C.7.1 Direct maximization 561
 - C.7.2 Using SAS optimizers 562
 - C.7.3 Maximum likelihood estimation of gamma model 565
 - C.7.4 Testing the gamma model 567

Index 571