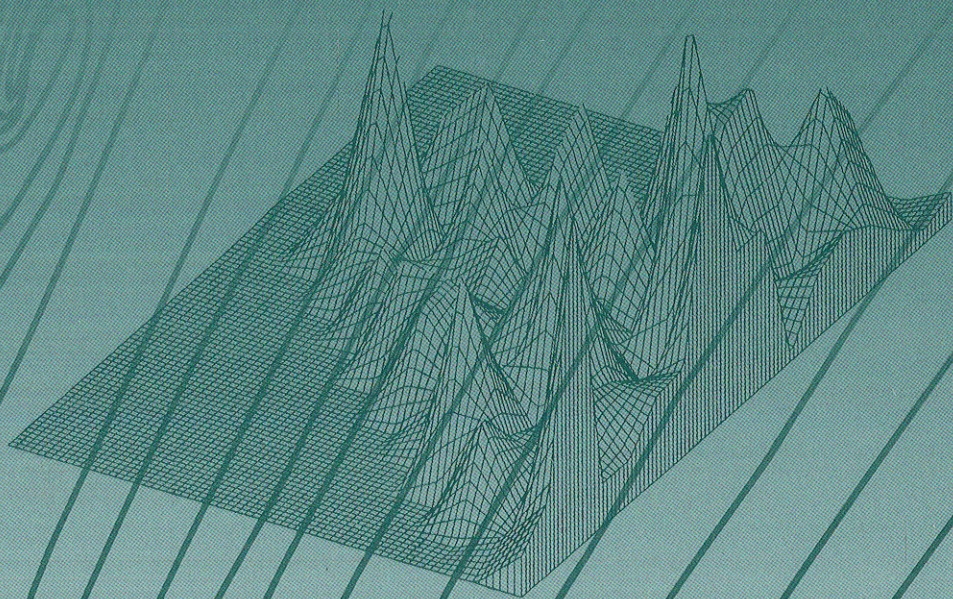


DYNAMIC MODELING AND ECONOMETRICS  
IN ECONOMICS AND FINANCE

# MODERN LINEAR AND NONLINEAR ECONOMETRICS

BY  
JOSEPH PLASMANS



 Springer

# Contents

<b>I</b>	<b>Linear and Nonlinear Econometric Inference: Estimation and Testing</b>	<b>1</b>
<b>1</b>	<b>Estimation in Linear and Nonlinear Models</b>	<b>5</b>
1.1	Introduction to linear and nonlinear optimization . . . . .	5
1.1.1	Nonlinear least squares . . . . .	6
1.1.2	Nonlinear maximum likelihood . . . . .	7
1.2	Econometric methods of nonlinear estimation . . . . .	10
1.2.1	Gauss method . . . . .	10
1.2.2	Method of scoring . . . . .	13
1.2.3	Quasi-Gauss method . . . . .	13
1.2.4	Marquardt method . . . . .	14
1.2.5	Quadratic hill-climbing method . . . . .	14
1.2.6	Concluding remarks . . . . .	14
<b>2</b>	<b>Generalized Method of Moments</b>	<b>19</b>
2.1	Endogeneity bias: two examples . . . . .	19
2.2	The method of moments . . . . .	21
2.2.1	Some examples . . . . .	22
2.2.2	MoM encompasses many estimation methods . . . . .	23
2.3	Generalized method of moments . . . . .	27
2.3.1	Example: GMM estimators based on Euler equations . . . . .	28
2.3.2	Three empirical examples . . . . .	30
2.3.3	Exercises . . . . .	31
2.4	Some concluding remarks . . . . .	32
<b>3</b>	<b>Testing in Linear and Nonlinear Models</b>	<b>33</b>
3.1	Nested model tests . . . . .	34
3.1.1	Lagrange multiplier test . . . . .	34
3.1.2	Wald test . . . . .	35
3.1.3	Likelihood ratio test . . . . .	35
3.1.4	Confidence intervals and hypotheses tests . . . . .	36
3.1.5	Recapitulating and extending nested hypotheses . . . . .	38
3.1.6	Examples of nested model tests . . . . .	39
3.2	Nonnested model tests . . . . .	47

3.2.1	Cox test for two different linear models . . . . .	48
3.2.2	Cox test for two different nonlinear models . . . . .	50
3.3	Theoretical and empirical exercises . . . . .	53

## II Time Series Analysis 55

<b>4</b>	<b>A Typology of Dynamic Models</b> . . . . .	<b>59</b>
4.1	Autoregressive distributed lag models . . . . .	59
4.2	The partial adjustment model . . . . .	60
4.3	The error correction mechanism . . . . .	63
<b>5</b>	<b>Univariate <i>ARIMA</i> Models</b> . . . . .	<b>65</b>
5.1	Stationary processes . . . . .	66
5.2	Autoregressive (time series) processes . . . . .	68
5.2.1	Stationary autoregressive processes . . . . .	68
5.2.2	Estimation and identification of <i>AR</i> processes . . . . .	69
5.3	Moving average (time series) processes . . . . .	72
5.3.1	Definition . . . . .	73
5.3.2	Identification of an <i>MA</i> process . . . . .	74
5.3.3	Parameter estimation of an <i>MA</i> ( <i>q</i> ) process . . . . .	75
5.4	<i>ARMA</i> models . . . . .	75
5.4.1	Stationarity restrictions . . . . .	75
5.4.2	The <i>ARMA</i> (1, 1) model . . . . .	76
5.5	Testing for unit roots . . . . .	79
5.5.1	Testing for unit roots in a first order autoregressive model . . . . .	79
5.5.2	Testing for unit roots in higher order <i>AR</i> models . . . . .	83
5.5.3	Multiple unit roots . . . . .	85
5.5.4	Seasonal unit roots . . . . .	88
5.6	<i>ARIMA</i> models . . . . .	89
5.7	Box-Jenkins approach for <i>ARIMA</i> models . . . . .	90
5.7.1	Identification of a tentative time series model . . . . .	90
5.7.2	Estimation of a time series model . . . . .	91
5.7.3	Diagnostic Checking . . . . .	94
5.8	Time series with aberrant observations . . . . .	98
5.8.1	Definition and problems . . . . .	98
5.8.2	Testing for and dealing with aberrant observations . . . . .	101
5.8.3	Detecting and estimating aberrant observations . . . . .	103
5.9	Forecasting of <i>ARIMA</i> models . . . . .	104
5.9.1	Forecasting <i>AR</i> processes . . . . .	105
5.9.2	Forecasting <i>MA</i> processes . . . . .	108
5.9.3	Forecasting <i>ARMA</i> processes . . . . .	109
5.9.4	Forecasting an <i>ARIMA</i> process . . . . .	111
5.9.5	<i>Ad hoc</i> forecasting methods . . . . .	113
5.9.6	Forecasts with density functions . . . . .	117
5.10	Cases and exercises about <i>ARIMA</i> models . . . . .	121

5.10.1	Theoretical exercises . . . . .	121
5.10.2	Solved (empirical) cases . . . . .	129
5.10.3	Empirical exercises . . . . .	148
5.10.4	Unsolved cases . . . . .	151
<b>6</b>	<b>Cointegration and Transfer Functions</b>	<b>153</b>
6.1	Cointegration . . . . .	153
6.1.1	A simple example . . . . .	153
6.1.2	Definition and properties . . . . .	154
6.2	Causality . . . . .	156
6.3	Transfer function modeling . . . . .	157
6.3.1	Single output single input models . . . . .	157
6.3.2	Intervention analysis . . . . .	159
6.3.3	Theoretical and empirical examples and exercises . . . . .	161
<b>7</b>	<b>Multivariate Time Series</b>	<b>165</b>
7.1	Vector autoregressive models . . . . .	166
7.1.1	A simple bivariate $VAR(1)$ . . . . .	166
7.1.2	$VAR(p)$ models . . . . .	170
7.1.3	Structural $VAR$ models . . . . .	178
7.2	$VARMA$ models . . . . .	181
7.2.1	Multivariate cointegration . . . . .	181
7.2.2	Multivariate causality . . . . .	185
7.2.3	Dynamic simultaneous equations models . . . . .	186
7.2.4	$DSEMs$ and $SVARs$ . . . . .	187
7.3	Exercises and cases . . . . .	188
7.3.1	Solved theoretical exercises . . . . .	188
7.3.2	Solved empirical exercise . . . . .	189
7.3.3	Solved empirical cases . . . . .	191
7.3.4	Unsolved exercises . . . . .	191
<b>8</b>	<b>Varying Parameter Models</b>	<b>193</b>
8.1	Regime switching models . . . . .	193
8.1.1	Specification and estimation of regime switching models based on observables . . . . .	194
8.1.2	Specification and estimation of regime switching models based on unobservables . . . . .	195
8.1.3	Solved empirical case for regime switching models . . . . .	198
8.2	Volatility modeling . . . . .	199
8.2.1	Univariate $ARCH$ models . . . . .	203
8.2.2	The symmetric $GARCH$ class of models . . . . .	204
8.2.3	Other functional forms of $GARCH$ models . . . . .	216
8.2.4	Multivariate $GARCH$ processes . . . . .	221
8.2.5	Exercises and cases . . . . .	229

<b>III</b>	<b>Categorical and Limited Dependent Variables</b>	<b>237</b>
9	Discrete Choice Models	241
9.1	Binary choice models . . . . .	241
9.1.1	Regression approach . . . . .	242
9.1.2	Repeated observations for discrete choice . . . . .	243
9.1.3	Marginal effects (or 'slopes') . . . . .	245
9.1.4	Forecasts . . . . .	246
9.1.5	No repeated observations . . . . .	246
9.1.6	Index function models: latent variables representation . . . . .	247
9.2	Multiple response models . . . . .	248
9.2.1	Ordered response models . . . . .	248
9.2.2	Multinomial models . . . . .	249
9.3	Cases and exercises . . . . .	251
9.3.1	Solved cases . . . . .	251
9.3.2	Exercises . . . . .	255
10	Limited Responses, Duration and Count Data	257
10.1	Censoring and truncation . . . . .	257
10.1.1	Problems raised by censoring . . . . .	257
10.1.2	Tobit models for censoring . . . . .	258
10.2	Models for duration data . . . . .	259
10.2.1	Parametric models of duration . . . . .	260
10.3	Count data . . . . .	262
10.3.1	Poisson model . . . . .	263
10.3.2	Negative binomial model . . . . .	265
10.3.3	Zero-inflated count models . . . . .	265
10.4	Exercises . . . . .	266
<b>IV</b>	<b>Panel Data Analysis</b>	<b>267</b>
11	Linear Panel Data Models	271
11.1	Panel data models with constant coefficients . . . . .	273
11.2	Intercepts varying over individuals . . . . .	274
11.2.1	$\mu_i$ fixed . . . . .	275
11.2.2	$\mu_i$ random . . . . .	278
11.2.3	Testing for random effects . . . . .	282
11.2.4	Random effects versus fixed effects . . . . .	283
11.3	Intercepts varying over individuals and time . . . . .	284
11.3.1	$\mu_i$ and $\lambda_t$ fixed: dummy variables model . . . . .	285
11.3.2	$\mu_i$ and $\lambda_t$ random: error components model . . . . .	286
11.3.3	Specification tests . . . . .	288
11.3.4	Fixed or random effects? . . . . .	288
11.4	All coefficients varying over individuals . . . . .	289
11.4.1	$\beta_{ki}$ fixed: SUR . . . . .	289

11.4.2	$\beta_{ki}$ random: Swamy's random coefficient model . . . . .	293
11.5	All coefficients vary over individuals and time . . . . .	295
11.5.1	Fixed coefficients . . . . .	296
11.5.2	Stochastic coefficients: Hsiao's model . . . . .	296
11.6	Advantages of panel data reconsidered . . . . .	297
11.7	Incomplete panels and selection bias . . . . .	300
11.7.1	Incomplete panels . . . . .	301
11.7.2	Attrition and selection bias . . . . .	302
11.8	Dynamic linear panel data models . . . . .	303
11.9	Empirical cases and exercises . . . . .	309
11.9.1	Case 1. Investment and market value of firms . . . . .	309
11.9.2	Case 2. Money flows and the performance of hedge funds . . . . .	315
11.9.3	Exercises . . . . .	319
<b>12</b>	<b>Nonlinear Panel Data Models</b>	<b>321</b>
12.1	FE estimation for logit and probit . . . . .	321
12.1.1	Logit models and conditional MLE . . . . .	321
12.1.2	FEs in probit models and a semiparametric estimator . . . . .	323
12.2	RE estimation . . . . .	324
12.2.1	ML estimation . . . . .	324
12.3	Panel count data models . . . . .	325
12.3.1	Fixed Effects Poisson models . . . . .	325
12.3.2	Random Effects Poisson models . . . . .	325
12.4	Cases and exercises . . . . .	326
12.4.1	Case 1. Firms' decision to report their R&D expenditures . . . . .	326
12.4.2	Case 2. Count data model for patents-R&D relationship . . . . .	328
12.4.3	Exercise . . . . .	328
<b>A</b>	<b>Nonlinear Optimization and Estimation</b>	<b>333</b>
A.1	General nonlinear optimization problem . . . . .	333
A.2	Gradient methods of nonlinear estimation . . . . .	334
A.2.1	Steepest descent . . . . .	335
A.2.2	Newton (-Raphson) . . . . .	338
A.2.3	Quasi-Newton procedures . . . . .	339
A.3	Constrained nonlinear optimization methods . . . . .	343
A.3.1	Reparameterization . . . . .	343
A.3.2	Transformation of the objective function . . . . .	344
A.3.3	Dual methods . . . . .	345
A.3.4	Extended (augmented) Lagrange function method . . . . .	345
<b>B</b>	<b>Mathematical Formulation of GMM</b>	<b>349</b>
B.1	Redefining GMM . . . . .	349
B.2	Assumptions and properties . . . . .	350
B.3	Nonlinear two stage least squares . . . . .	351
<b>C</b>	<b>Stability Criteria for <math>AR(p)</math> Models</b>	<b>353</b>

<b>D</b>	<b>MLE of the RSM with Endogenous Prices</b>	<b>355</b>
<b>E</b>	<b>Volatility Modeling</b>	<b>359</b>
E.1	Detection and reduction of additive outliers . . . . .	359
E.2	Forecasting in $GARCH(p, q)$ models . . . . .	360
E.3	Generalized exponential distribution . . . . .	360
E.4	Generalized Student $t$ -distribution . . . . .	361
E.5	Aggregation of $GARCH$ processes . . . . .	361