# Contents

**Acknowledgements** ..... xv

**1 Introduction and Overview** ..... 1
1.1 What is Experimetrics? ..... 1
1.2 Experimental Design ..... 2
1.3 The Experimetrics of Theory Testing ..... 3
1.4 Dependence in Experimental Data ..... 5
1.5 Parametric versus Non-parametric Approaches ..... 6
1.6 Structural Experimetrics ..... 7
1.7 Modelling Subject Heterogeneity ..... 9
1.8 Experimetrics of Other-regarding Preferences ..... 10
1.9 Experimetrics of Bounded Rationality ..... 11
1.10 Experimetrics of Learning ..... 12
1.11 What is in this Book? ..... 13

**2 Statistical Aspects of Experimental Design in Experimental Economics** ..... 17
2.1 Introduction ..... 17
2.2 The Average Treatment Effect ..... 17
2.3 Randomisation Techniques ..... 18
2.3.1 Completely randomised designs ..... 19
2.3.2 Factorial designs ..... 19
2.3.3 Block designs ..... 20
2.3.4 Within-subject designs ..... 20
2.3.5 Crossover designs ..... 21
2.3.6 ABA designs ..... 21
2.4 How Many Subjects? A Primer in Power Analysis ..... 21
2.4.1 The case of one sample ..... 21
2.4.2 Choosing the sample size in a treatment test ..... 24
2.4.3 Treatments with unequal costs ..... 26
2.4.4 Sample size in cluster designs ..... 27
2.5 Four Very Popular Experiments ..... 28

2.5.1 The ultimatum game ... 28
2.5.2 The dictator game ... 29
2.5.3 The trust game ... 29
2.5.4 The public goods game ... 29
2.6 Other Aspects of Design ... 30
2.6.1 The random lottery incentive (RLI) mechanism ... 30
2.6.2 The strategy method ... 31
2.6.3 "One-shot", "partners", and "strangers" designs ... 31
2.7 Summary and Further Reading ... 32

**3 Treatment Testing** ... 35
3.1 Introduction ... 35
3.2 The Mechanics of Treatment Testing ... 36
3.3 Testing with Discrete Outcomes ... 37
3.3.1 The binomial test ... 37
3.3.2 Fisher's exact test ... 38
3.3.3 The chi-squared test ... 41
3.3.4 The chi-squared test on a real data set ... 43
3.4 Testing for Normality ... 46
3.5 Treatment Testing ... 48
3.5.1 Parametric tests of treatment effects ... 48
3.5.2 Non-parametric tests of treatment effects: the Mann-Whitney test ... 51
3.5.3 The bootstrap ... 52
3.5.4 Tests comparing entire distributions ... 55
3.6 Testing for Gender Effects ... 57
3.7 Within-subject Tests ... 60
3.7.1 The Allais paradox ... 61
3.7.2 Preference reversals ... 64
3.7.3 Continuous outcome ... 65
3.8 Summary and Further Reading ... 68

**4 Theory Testing, Regression, and Dependence** ... 71
4.1 Introduction ... 71
4.2 Experimental Auctions ... 73
4.2.1 Overview of auction theory ... 73
4.2.2 Carrying out an experimental auction ... 75
4.2.3 The simulated auction data ... 75
4.3 Tests of Auction Theory ... 78
4.3.1 A test of RNNE in a second-price common value auction ... 78
4.4 Tests of Comparative Static Predictions ... 80
4.4.1 Standard treatment tests ... 80
4.4.2 Treatment testing using a regression ... 82
4.4.3 Accounting for dependence: the ultra-conservative test ... 82
4.4.4 Accounting for dependence in a regression ... 84
4.4.5 Accounting for dependence: the block bootstrap ... 85

4.5 Multiple Regression with Auction Data . . . 86
4.5.1 Introducing the effect of uncertainty . . . 86
4.5.2 Introducing the effect of experience . . . 88
4.5.3 Introducing the effect of cash balance . . . 89
4.6 Panel Data Estimators . . . 90
4.7 Multi-level Modelling . . . 92
4.8 Modelling Data from Contest Experiments . . . 97
4.8.1 The Tullock contest . . . 97
4.8.2 A contest experiment . . . 98
4.8.3 Analysis of data from contest experiment . . . 99
4.9 Meta-analysis . . . 102
4.10 Summary and Further Reading . . . 105

**5 Modelling of Decision Times Using Regression Analysis** . . . 107
5.1 Introduction . . . 107
5.2 The Decision-time Data . . . 108
5.3 A Theoretical Model of Effort Allocation . . . 109
5.4 An Econometric Model of Effort Allocation . . . 111
5.5 Panel Data Models of Effort Allocation . . . 116
5.6 Discussion of Results . . . 120
5.7 Post-estimation . . . 121
5.8 Summary and Further Reading . . . 123

**6 Dealing with Discreteness in Experimental Data** . . . 125
6.1 Introduction . . . 125
6.2 Binary Data . . . 126
6.2.1 Likelihood and log-likelihood explained . . . 126
6.2.2 Modelling choices between lotteries (the "house money effect") . . . 129
6.2.3 Marginal effects . . . 133
6.2.4 Wald tests and LR tests . . . 134
6.2.5 Analysis of ultimatum game data . . . 135
6.2.6 The strategy method . . . 138
6.3 The `ml` Routine in STATA . . . 140
6.4 Structural Modelling . . . 141
6.5 Further Structural Modelling . . . 144
6.5.1 The heterogeneous agent model . . . 144
6.5.2 The delta method . . . 147
6.5.3 Another example using the delta method . . . 148
6.6 Other Data Types . . . 149
6.6.1 Interval data: the interval regression model . . . 149
6.6.2 Continuous (exact) data . . . 152
6.6.3 Censored data: the Tobit model . . . 155
6.7 The Ultimatum Game: Further Analysis . . . 160
6.7.1 Further tests of gender effects . . . 160

6.7.2 The proposer's decision as a risky choice problem ..... 161
6.8 Summary and Further Reading ..... 164

**7 Ordinal Data in Experimetrics** ..... 167
7.1 Introduction ..... 167
7.2 Ordered Outcomes: The Case for Special Treatment ..... 168
7.3 The Ordered Probit Model: Theory ..... 169
7.4 Interpreting the Cut-point Parameters ..... 171
7.5 Application to Data on Emotions ..... 172
7.6 Application to Data on Strength of Preference ..... 177
7.7 Summary and Further Reading ..... 181

**8 Dealing with Heterogeneity: Finite Mixture Models** ..... 183
8.1 Introduction ..... 183
8.2 Mixture of Two Normal Distributions ..... 184
8.2.1 Data and model ..... 184
8.2.2 Posterior type probabilities ..... 186
8.2.3 The estimation program ..... 186
8.2.4 Results ..... 187
8.3 The `fmm` Command in STATA ..... 188
8.4 A Mixture Model for the "Acquiring a Company" Task ..... 190
8.5 A Mixture Model for Giving in a Public Goods Experiment ..... 193
8.5.1 Background ..... 193
8.5.2 Experiment ..... 194
8.5.3 The data ..... 195
8.5.4 The finite mixture two-limit Tobit model with tremble ..... 197
8.5.5 Program ..... 201
8.5.6 Results ..... 206
8.5.7 Posterior type probabilities ..... 208
8.6 Summary and Further Reading ..... 210

**9 Simulating Experimental Data, and the Monte Carlo Method** ..... 211
9.1 Introduction ..... 211
9.2 Random Number Generation in STATA ..... 212
9.3 Simulating Data Sets ..... 214
9.3.1 Simulating data from a linear model ..... 214
9.3.2 Simulating panel data ..... 216
9.3.3 Simulating dynamic panel data ..... 217
9.3.4 Simulating binary panel data ..... 219
9.4 Monte Carlo Investigation of the Hausman Test ..... 220
9.5 Summary and Further Reading ..... 224

**10 Introduction to the Method of Maximum Simulated Likelihood (MSL) ..... 227**
10.1 Introduction ..... 227
10.2 The Principle of Maximum Simulated Likelihood (MSL) ..... 228
10.3 Halton Draws ..... 229
10.3.1 The case for using Halton draws ..... 229
10.3.2 Generating Halton draws in STATA ..... 230
10.3.3 Halton draws for panel data estimation ..... 233
10.4 The Random Effects Probit Model ..... 234
10.4.1 Model ..... 234
10.4.2 Simulation ..... 236
10.4.3 Estimation by MSL ..... 238
10.4.4 Preparation of data for estimation ..... 239
10.4.5 The likelihood evaluator ..... 240
10.4.6 Complete annotated code ..... 244
10.4.7 Results ..... 246
10.5 The Random Effects Two-limit Tobit Model ..... 248
10.5.1 Construction of log-likelihood function ..... 249
10.5.2 Estimation by MSL ..... 250
10.5.3 STATA code ..... 251
10.5.4 Results from random effects two-limit Tobit model ..... 253
10.6 Summary and Further Reading ..... 255

**11 Dealing with Zeros: Hurdle Models ..... 257**
11.1 Introduction ..... 257
11.2 Review of Tobit and Random Effects Tobit ..... 258
11.3 The Need for Hurdle Models ..... 260
11.4 The Double Hurdle Model and Variants ..... 261
11.4.1 *p*-Tobit ..... 261
11.4.2 Double hurdle ..... 261
11.4.3 The single hurdle model ..... 263
11.5 The Panel Hurdle Model ..... 264
11.5.1 The basic model ..... 264
11.5.2 The panel single hurdle model ..... 265
11.5.3 Construction of likelihood function ..... 265
11.5.4 Panel hurdle with upper censoring ..... 266
11.5.5 Panel hurdle model with tremble ..... 266
11.5.6 Panel hurdle model with dependence ..... 267
11.5.7 Obtaining posterior probabilities ..... 268
11.5.8 Estimation ..... 269
11.5.9 STATA code and simulation ..... 269
11.6 A Panel Hurdle Model of Dictator Game Giving ..... 275
11.6.1 The experiment ..... 275
11.6.2 Estimation ..... 278
11.6.3 Results ..... 279

11.7 A Panel Hurdle Model of Contribution in a Public Goods Game ..... 282
11.8 Summary and Further Reading ..... 288

**12 Choice under Risk: Theoretical Issues** ..... 291
12.1 Introduction ..... 291
12.2 Utility Functions and Risk Aversion ..... 291
12.3 Lottery Choice ..... 295
12.4 Stochastic Dominance ..... 298
12.5 Non-expected Utility Models ..... 299
12.5.1 Weighting functions ..... 299
12.6 Stochastic Models of Choice under Risk ..... 302
12.7 Summary and Further Reading ..... 304

**13 Choice under Risk: Econometric Modelling** ..... 307
13.1 Introduction ..... 307
13.2 The Choice Models ..... 310
13.2.1 The framework ..... 310
13.2.2 Incorporating violations of EU ..... 311
13.2.3 The Fechner model ..... 312
13.2.4 The Random Preference (RP) model ..... 312
13.2.5 Dominance problems in the RP model ..... 313
13.2.6 The tremble parameter ..... 313
13.2.7 The role of experience ..... 314
13.2.8 Between-subject variation and the sample log-likelihood ..... 315
13.2.9 Posterior estimation of risk attitude ..... 316
13.3 Simulation and Estimation ..... 316
13.3.1 Data generating process ..... 316
13.3.2 The STATA code ..... 317
13.3.3 The simulated data ..... 325
13.3.4 Output from estimation routines ..... 326
13.4 Results and Post-estimation ..... 327
13.4.1 The model estimates ..... 327
13.4.2 Vuong's non-nested likelihood ratio test ..... 328
13.4.3 Clarke's non-parametric non-nested test ..... 329
13.4.4 Obtaining individual risk attitudes ..... 331
13.4.5 Obtaining closeness to indifference ..... 331
13.4.6 Simulation of decision times ..... 332
13.5 Summary and Further Reading ..... 333

**14 Optimal Design in Binary Choice Experiments** ..... 335
14.1 Introduction ..... 335
14.2 Rudiments of Experimental Design Theory ..... 337
14.2.1 The principle of D-optimal design ..... 337
14.2.2 Simple linear regression ..... 338
14.2.3 Simple probit and simple logit ..... 339

14.3 The Random Preference (RP) Model Revisited ..... 341
14.4 Application of D-optimal Design Theory to a Risky Choice Experiment ..... 344
14.5 Optimal Design in the Presence of a Tremble Parameter ..... 345
14.6 Optimal Design for a Sample of Subjects ..... 347
14.6.1 Choice of design used in Chapter 13 ..... 348
14.7 Summary and Further Reading ..... 349

**15 Social Preference Models** ..... 351
15.1 Introduction ..... 351
15.2 Estimation of Preference Parameters from Dictator Game Data ..... 352
15.2.1 The framework ..... 352
15.2.2 The Andreoni-Miller data ..... 352
15.2.3 Estimating the parameters of a CES utility function ..... 357
15.3 A Model of Altruism with Binding Non-negativity Constraints ..... 360
15.3.1 Background ..... 360
15.3.2 The model ..... 360
15.3.3 Estimation ..... 363
15.3.4 Results ..... 366
15.4 Finite Mixture Models of Altruism ..... 367
15.4.1 The experiment ..... 368
15.4.2 The data ..... 368
15.4.3 A mixture model of fairness ..... 368
15.4.4 The "fairness ideals" ..... 370
15.4.5 The econometric model ..... 370
15.4.6 The program and results ..... 371
15.5 Estimation of Social Preference Parameters Using Discrete Choice Models ..... 374
15.5.1 The setting ..... 374
15.5.2 Formalising the criteria for choosing between allocations ..... 375
15.5.3 Data ..... 376
15.5.4 The conditional logit model (CLM) ..... 376
15.5.5 Results ..... 378
15.5.6 The effect of subject characteristics ..... 378
15.6 Summary and Further Reading ..... 379

**16 Repeated Games and Quantal Response Models** ..... 383
16.1 Introduction ..... 383
16.2 Analysis of Repeated Game Data ..... 384
16.2.1 Computing a mixed strategy Nash equilibrium ..... 384
16.2.2 Non-parametric tests on repeated game data ..... 385
16.3 Quantal Response Equilibrium (QRE) ..... 389
16.3.1 Theory of QRE ..... 389
16.3.2 Computing the probabilities in the QRE model ..... 391
16.4 Estimation of the QRE Model ..... 392
16.5 The Risk-averse QRE Model ..... 397

16.6 QRE Applied to Contest Data ..... 400
16.7 Summary and Further Reading ..... 406

**17 Depth of Reasoning Models** ..... 407
17.1 Introduction ..... 407
17.2 A Level-k Model for the Beauty Contest Game ..... 408
17.3 The Cognitive Hierarchy Model ..... 413
17.4 Summary and Further Reading ..... 418

**18 Learning Models** ..... 419
18.1 Introduction ..... 419
18.2 Directional Learning (DL) ..... 420
18.3 Data Used for Estimation of RL, BL and EWA ..... 423
18.4 Notation Used in RL, BL and EWA ..... 423
18.5 Reinforcement Learning (RL) ..... 424
18.5.1 Program and results for RL ..... 425
18.6 Belief learning (BL) ..... 427
18.6.1 Program and results for BL ..... 429
18.7 The Experience Weighted Attraction (EWA) Model ..... 431
18.7.1 Introduction to EWA ..... 431
18.7.2 Simulation of data set using EWA ..... 432
18.7.3 Estimation of EWA Model ..... 434
18.7.4 Results from EWA Model ..... 436
18.8 Summary and Further Reading ..... 439

**19 Summary and Conclusion** ..... 441
19.1 Experimental Design Issues ..... 441
19.2 Experimetrics and Theory Testing ..... 443
19.3 Data Features ..... 443
19.4 Experimetrics of Social Preferences ..... 444
19.5 Risk Experimetrics ..... 445
19.6 The Experimetrics of Games ..... 447
19.7 Heterogeneity ..... 448

**A List of Data Files and Other Files** ..... 451

**B List of STATA Commands** ..... 453

**C Choice Problems Used in Chapters 5 and 13** ..... 461

**References** ..... 463

**Index** ..... 473