Contents

Preface xv

Part A: DYNAMIC BAYESIAN MODELLING
Theory and Applications

Chapter 1  Practical Modelling and Forecasting  3
1.1 The Nature of Time Series  3
1.2 Time Series Analysis vs Forecasting  4
1.3 Model Forms  5
1.4 Dynamic Systems  6
1.5 The Bayesian Approach to Forecasting  9
1.6 Future Developments  10
1.7 Reference Material  11

Chapter 2  Methodological Framework  13
2.1 The Dynamic Linear Model  13
  2.1.1 Time and Order  15
2.2 Bayesian Analysis  16
  2.2.1 Sequential Analysis  16
2.3 Subjective Intervention  17
2.4 Forecasting  18
2.5 Distributional Forms  19
2.6 Monitoring  20
2.7 Variance Analysis  21
2.8 Smoothing  23
2.9 Component Models  24
  2.9.1 Block Structuring  25
2.10 Summary  26
2.11 References  27

Chapter 3  Analysis of the DLM  29
3.1 Model Form and Notation  29
3.2 Updating: Prior to Posterior Analysis  30
3.2.1 Bayes’ Theorem 30
3.2.2 Prior Information 30
3.2.3 Forecasts 31
3.2.4 Likelihood 34
3.2.5 Posterior Information 34
3.2.6 Evolution 37

3.3 Forward Intervention 37
3.3.1 Arbitrary Intervention 38

3.4 Smoothing 40

3.5 Component Forms 42
3.5.1 Polynomial Trend Components 42
3.5.2 Seasonal Component Models 44
3.5.3 Harmonic Analysis 47
3.5.4 Regression Components 51

3.6 Superposition: Block Structured Models 51
3.6.1 Block Discounting 52
3.6.2 Component Intervention 54

3.7 Variance Learning 55
3.7.1 Variance Laws 58
3.7.2 Variance Discounting 58
3.7.3 Variance Intervention 60
3.7.4 Smoothing 60

3.8 Forecast Monitoring 62
3.8.1 Bayes Factors 62
3.8.2 Automatic Monitoring 64
3.8.3 Cumulative Evidence 64
3.8.4 Monitor Design 65
3.8.5 General Monitoring Scheme 65

3.9 Error Analysis 69

3.10 References 69

3.11 Exercises 70

Appendix 3.1 Review of Distribution Theory 75

Univariate Normal Distribution 75
Sums of Normal Variables 76
Multivariate Normal Distribution 76
Linear Transformations 77
Marginal Distributions 77
Conditional Distributions 77
Gamma Distribution 78
Univariate Student-t Distribution 78
Multivariate Student-t Distribution 79
Appendix 3.2 Classical Time Series Models 83

Autoregressive Models 83
Moving Average Models 84
Autoregressive Moving Average Models 84
DLM Representation of ARMA Models 84
Alternative Representations of AR Models 85
Stationarity 86
Modelling with ARMA Models 87
Forecast Function Equivalence of ARMA and DLM 88
References 89

Chapter 4 Application: Turkey Chick Sales 91

4.1 Preliminary Investigation 92
  4.1.1 Stabilising Variation 92
  4.1.2 Seasonal Pattern Changes 94
  4.1.3 Forecasting Transformed Series 94
  4.1.4 Assessing Transformations 95

4.2 Live Forecasting 102
  4.2.1 Forecast Analysis 103

4.3 Retrospective Perspectives 109
  4.3.1 The View From 1977 110
  4.3.2 The Global Picture 111
  4.3.3 Final Remarks 116

4.4 Summary 119
4.5 Exercises 119

Chapter 5 Application: Market Share 121

5.1 Exploratory Analysis 121
5.2 Dynamic Regression Model 124
5.3 A First Analysis 125
  5.3.1 Scaling Regression Variables 127

5.4 Analysis with Rescaled Promotions 129
  5.4.1 Dynamic Analysis 129
5.5 Final Analysis 135
5.6 'What if?' Projections 139

5.7 Contemporaneous and Lagged Relationships 142
Chapter 6  Application: Marriages in Greece  

6.1 Analysis I  148
6.2 Analysis II  151
6.3 Analysis III  154
6.4 Conclusions  156
6.5 1972: Case for the Defence  157
6.6 Regional Analysis  158
   6.6.1 Athens, Macedonia  158
   6.6.2 Epirus, Peloponnesos, Thessaly, Thrace  158
   6.6.3 Rest of Mainland  159
   6.6.4 Crete, Aegean Islands, Ionian Islands  159

6.7 Summary  162
6.8 Exercises  163

Chapter 7  Further Examples and Exercises  

7.1 Nile River Volume  165
7.2 Gas Consumption  170
7.3 Retail Sales  172
7.4 Inflation  174
7.5 United Kingdom Marriages  175
7.6 Housing Starts  177
7.7 Telephone Calls  180
7.8 Perceptual Speed  182
7.9 Savings  184
7.10 Air Freight  186
7.11 London Mortality  192
7.12 Share Earnings  194
7.13 Passenger Car Sales  198
7.14 Phytoplankton  199
7.15 Further Data Sets  202
7.16 Data Set List  227
7.17 References  230
Part B: INTERACTIVE TIME SERIES ANALYSIS AND FORECASTING

Chapter 8 Installing BATS
8.1 Documentation 235
  8.1.1 User Guide 235
  8.1.2 Reference Guide 236
8.2 How to Use This Guide 236
  8.2.1 Typographical Conventions 237
8.3 Before You Begin 238
8.4 Installing BATS 238
8.5 Using BATS with Floppy Disc Drives 239
8.6 Using BATS with A Fixed Disc Drive 240
8.7 Using Expanded/Extended Memory 241
8.8 Microsoft Windows 241

Chapter 9 Tutorial: Introduction to BATS
9.1 Starting a Session 243
9.2 Operating with Menus 243
9.3 Traversing the Menu Hierarchy 245
9.4 Examining Data 246
9.5 Ending a Session 251
9.6 Summary of Operations 252
9.7 Getting out of Trouble 253
9.8 Items Covered in This Tutorial 253

Appendix 9.1 Files and Directories
  File Types 255
  File Masks 256
  Directories 257
  The Working Directory 258
  Summary 258

Chapter 10 Tutorial: Introduction to Modelling
10.1 Dynamic Modelling 259
10.2 Specifying the Steady Model 260
10.3 Prediction 262
  10.3.1 Changing the Model Dynamic 265
  10.3.2 Modelling Known Variance 266
10.4 Forecasting and Model Estimation 266
  10.4.1 Retrospective Analysis 269
10.5 Summary of Operations 273
10.6 Extending the Model: Explanatory Variables 274
  10.6.1 Specifying a Regression Component 274
10.7 Data Transformations: New Series from Old 280
10.8 Prediction with Regressors 282
10.9 Multiple Regressions 284
10.10 Summary of Operations 285
10.11 Extending the Model: Seasonal Patterns 286
  10.11.1 Specifying a Seasonal Component 286
  10.11.2 Restricted Seasonal Patterns 291
  10.11.3 Prediction 295
  10.11.4 Prior Specification for Seasonal Components 297
10.12 Summary of Operations 298
10.13 Items Covered in This Tutorial 299

Chapter 11  Tutorial: Advanced Modelling 301

11.1 Data and Model 301
11.2 Preliminary Analysis 303
11.3 Monitoring Forecast Performance 306
  11.3.1 Setting a Monitor 306
  11.3.2 Analysis with Monitoring 307
  11.3.3 Modes of Automatic Signal Handling 311
  11.3.4 Customising the Monitor 312
  11.3.5 More Analysis 313
11.4 Summary of Operations 316
11.5 Intervention Facilities 317
11.6 Summary of Operations 324
11.7 Forward Intervention 325
  11.7.1 Taking the Analysis Further 329
11.8 Summary of Operations 330
11.9 Putting It All Together 331
11.10 Summary of Operations 337
11.11 Items Covered in This Tutorial 338
11.12 Digression: On the Identification of Change 338
11.13 References 340

Chapter 12  Tutorial: Modelling with Incomplete Data 341

12.1 Communicating Missing Values 342
12.2 Summary of Operations 345
12.3 Analysis with Missing Values I: Response Series 346
12.4 Analysis with Missing Values II: Regressor Series 349
12.5 Summary of Operations 353
12.6 Prediction with Missing Regressors 354
12.7 Summary of Operations 355
12.8 Data Transformations with Missing Values 355
12.9 Summary of Operations 357
12.10 Items Covered in This Tutorial 357

Chapter 13  Tutorial: Data Management 359
13.1 Free Format Data Files 359
  13.1.1 Reading the File 360
  13.1.2 Writing the File 361
13.2 BATS Format Data Files 362
  13.2.1 Storing and Retrieving Model Definitions 362
13.3 Summary of Operations 364
13.4 Subset Selection 365
13.5 Temporal Aggregation 366
  13.5.1 Aggregation and Structural Change 367
13.6 Editing and Transformations 368
13.7 Summary of Operations 369
13.8 Items Covered in This Tutorial 370
13.9 Finale 370

Part C: BATS REFERENCE

Chapter 14  Communications 373
14.1 Menus 373
14.2 Lists 375
14.3 Tables 376
14.4 Dialogue Boxes 378
14.5 Graphs 379

Chapter 15  Menu Descriptions 381
15.1 Menu Trees 381
  15.1.1 Main Menu Tree 381
  15.1.2 Floating Menus 384
15.2 Root 385
15.3 Data 386
15.4 Data/Input-Output 387
15.5 Data/Input-Output/Read 389
15.6 Data/Input-Output/Write 389
15.7 Data/Explore 390
15.8 Data/Explore/Seas 393
15.9 Reset 393
15.10 Model 394
15.11 Model/Components 395
15.12 Model/Components/Trend 396
15.13 Model/Components/Seasonal 396
15.14 Model/Interrupts 397
15.15 Model/Discount 397
15.16 Fit 398
15.17 Fit/Existing-Prior 398
15.18 Fit/Existing-Prior/Seasonal 399
15.19 Forecast Priors 400
15.20 Configuration 400
15.21 Forward Intervention 402
15.22 Monitor Signal 403

Index 405