

ECONOMIC FORECASTING

0(>5<XXXX><X><XxX><Xx><X><X><X>0<X><X>C><X>000<XXX>>&00<X><X><X><X><X><X>

GRAHAM ELLIOTT AND
ALLAN TIMMERMANN

PRINCETON UNIVERSITY PRESS
PRINCETON AND OXFORD

Preface xiii

I Foundations

- 1 Introduction 3
 - 1.1 Outline of the Book 3
 - 1.2 Technical Notes 12
- 2 Loss Functions 13
 - 2.1 Construction and Specification of the Loss Function 14
 - 2.2 Specific Loss Functions 20
 - 2.3 Multivariate Loss Functions 28
 - 2.4 Scoring Rules for Distribution Forecasts 29
 - 2.5 Examples of Applications of Forecasts in Macroeconomics and Finance 31
 - 2.6 Conclusion 37
- 3 **The Parametric Forecasting Problem** 39
 - 3.1 Optimal Point Forecasts 41
 - 3.2 Classical Approach 47
 - 3.3 Bayesian Approach 54
 - 3.4 Relating the Bayesian and Classical Methods 56
 - 3.5 Empirical Example: Asset Allocation with Parameter Uncertainty 59
 - 3.6 Conclusion 62
- 4 Classical Estimation of Forecasting Models 63
 - 4.1 Loss-Based Estimators 64
 - 4.2 Plug-In Estimators 68
 - 4.3 Parametric versus Nonparametric Estimation Approaches 73
 - 4.4 Conclusion 74
- 5 Bayesian Forecasting Methods 76
 - 5.1 Bayes Risk 77
 - 5.2 Ridge and Shrinkage Estimators 81
 - 5.3 Computational Methods 83
 - 5.4 Economic Applications of Bayesian Forecasting Methods 85
 - 5.5 Conclusion 88
- 6 **Model Selection** 89
 - 6.1 Trade-Offs in Model Selection 90
 - 6.2 Sequential Hypothesis Testing 93
 - 6.3 Information Criteria 96
 - 6.4 Cross Validation 99

- 6.5 Lasso Model Selection 101
- 6.6 Hard versus Soft Thresholds: Bagging 104
- 6.7 Empirical Illustration: Forecasting Stock Returns 106
- 6.8 Properties of Model Selection Procedures 115
- 6.9 Risk for Model Selection Methods: Monte Carlo Simulations 121
- 6.10 Conclusion 125
- 6.11 Appendix: Derivation of Information Criteria 126

II Forecast Methods

- 7 Univariate Linear Prediction Models 133**
 - 7.1 ARMA Models as Approximations 134
 - 7.2 Estimation and Lag Selection for ARMA Models 142
 - 7.3 Forecasting with ARMA Models 147
 - 7.4 Deterministic and Seasonal Components 155
 - 7.5 Exponential Smoothing and Unobserved Components 159
 - 7.6 Conclusion 164

- 8 Univariate Nonlinear Prediction Models 166**
 - 8.1 Threshold Autoregressive Models 167
 - 8.2 Smooth Transition Autoregressive Models 169
 - 8.3 Regime Switching Models 172
 - 8.4 Testing for Nonlinearity 179
 - 8.5 Forecasting with Nonlinear Univariate Models 180
 - 8.6 Conclusion 185

- 9 Vector Autoregressions 186**
 - 9.1 Specification of Vector Autoregressions 186
 - 9.2 Classical Estimation of VARs 189
 - 9.3 Bayesian VARs 194
 - 9.4 DSGE Models 206
 - 9.5 Conditional Forecasts 210
 - 9.6 Empirical Example 212
 - 9.7 Conclusion 217

- 10 Forecasting in a Data-Rich Environment 218**
 - 10.1 Forecasting with Factor Models 220
 - 10.2 Estimation of Factors 223
 - 10.3 Determining the Number of Common Factors 229
 - 10.4 Practical Issues Arising with Factor Models 232
 - 10.5 Empirical Evidence 234
 - 10.6 Forecasting with Panel Data 241
 - 10.7 Conclusion 243

- 11 Nonparametric Forecasting Methods 244**
 - 11.1 Kernel Estimation of Forecasting Models 245
 - 11.2 Estimation of Sieve Models 246
 - 11.3 Boosted Regression Trees 256
 - 11.4 Conclusion 259

- 12 Binary Forecasts 260**
 - 12.1 Point and Probability Forecasts for Binary Outcomes 261
 - 12.2 Density Forecasts for Binary Outcomes 265
 - 12.3 Constructing Point Forecasts for Binary Outcomes 269
 - 12.4 Empirical Application: Forecasting the Direction of the Stock Market 272
 - 12.5 Conclusion 273
- 13 Volatility and Density Forecasting 275**
 - 13.1 Role of the Loss Function 277
 - 13.2 Volatility Models 278
 - 13.3 Forecasts Using Realized Volatility Measures 288
 - 13.4 Approaches to Density Forecasting 291
 - 13.5 Interval and Quantile Forecasts 301
 - 13.6 Multivariate Volatility Models 304
 - 13.7 Copulas 306
 - 13.8 Conclusion 308
- 14 Forecast Combinations 310**
 - 14.1 Optimal Forecast Combinations: Theory 312
 - 14.2 Estimation of Forecast Combination Weights 316
 - 14.3 Risk for Forecast Combinations 325
 - 14.4 Model Combination 329
 - 14.5 Density Combination 336
 - 14.6 Bayesian Model Averaging 339
 - 14.7 Empirical Evidence 341
 - 14.8 Conclusion 344

III Forecast Evaluation

- 15 Desirable Properties of Forecasts 347**
 - 15.1 Informal Evaluation Methods 348
 - 15.2 Loss Decomposition Methods 352
 - 15.3 Efficiency Properties with Known Loss 355
 - 15.4 Optimality Tests under Unknown Loss 365
 - 15.5 Optimality Tests That Do Not Rely on Measuring the Outcome 368
 - 15.6 Interpreting Efficiency Tests 368
 - 15.7 Conclusion 371
- 16 Evaluation of Individual Forecasts 372**
 - 16.1 The Sampling Distribution of Average Losses 373
 - 16.2 Simulating Out-of-Sample Forecasts 375
 - 16.3 Conducting Inference on the Out-of-Sample Average Loss 380
 - 16.4 Out-of-Sample Asymptotics for Rationality Tests 385
 - 16.5 Evaluation of Aggregate versus Disaggregate Forecasts 388
 - 16.6 Conclusion 390

17	Evaluation and Comparison of Multiple Forecasts	391
17.1	Forecast Encompassing Tests	393
17.2	Tests of Equivalent Expected Loss: The Diebold-Mariano Test	397
17.3	Comparing Forecasting Methods: The Giacomini-White Approach	400
17.4	Comparing Forecasting Performance across Nested Models	403
17.5	Comparing Many Forecasts	409
17.6	Addressing Data Mining	413
17.7	Identifying Superior Models	415
17.8	Choice of Sample Split	417
17.9	Relating the Methods	418
17.10	In-Sample versus Out-of-Sample Forecast Comparison	418
17.11	Conclusion	420
18	Evaluating Density Forecasts	422
18.1	Evaluation Based on Loss Functions	423
18.2	Evaluating Features of Distributional Forecasts	428
18.3	Tests Based on the Probability Integral Transform	433
18.4	Evaluation of Multicategory Forecasts	438
18.5	Evaluating Interval Forecasts	440
18.6	Conclusion	441
IV Refinements and Extensions		
19	Forecasting under Model Instability	445
19.1	Breaks and Forecasting Performance	446
19.2	Limitations of In-Sample Tests for Model Instability	448
19.3	Models with a Single Break	451
19.4	Models with Multiple Breaks	455
19.5	Forecasts That Model the Break Process	456
19.6	Ad Hoc Methods for Dealing with Breaks	460
19.7	Model Instability and Forecast Evaluation	463
19.8	Conclusion	465
20	Trending Variables and Forecasting	467
20.1	Expected Loss with Trending Variables	468
20.2	Univariate Forecasting Models	470
20.3	Multivariate Forecasting Models	478
20.4	Forecasting with Persistent Regressors	480
20.5	Forecast Evaluation	486
20.6	Conclusion	489
21	Forecasting Nonstandard Data	490
21.1	Forecasting Count Data	491
21.2	Forecasting Durations	493
21.3	Real-Time Data	495

21.4 Irregularly Observed and Unobserved Data 498

21.5 Conclusion 504

Appendix 505

A.1 Kalman Filter 505

A.2 Kalman Filter Equations 507

A.3 Orders of Probability 514

A.4 Brownian Motion and Functional Central Limit Theory 515

Bibliography 517

Index 539