Preface xiii

I Foundations

1	Introduction	2
	nuroduction	- 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				
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				
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				
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				
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				
Nonparametric Forecasting Methods 244				

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

-		., , o, codoto 200		
	12.1	Point and Probability Forecasts for Binary Outcomes 261		
	12.2	Density Forecasts for Binary Outcomes 265		
	12.3			
	12.4			
		the Stock Market 272		
	12.5			
	-2.0			
13	Volatility and Density Forecasting 275			
	13.1	Role of the Loss Function 277		
	13.2	Volatility Models 278		
	13.3	•		
	13.4	- •		
	13.5	· · · · · · · · · · · · · · · · · · ·		
	13.6			
		Copulas 306		
	13.8	-		
	13.0	Conclusion 500		
14	Forecast Combinations 310			
• •	14.1	Optimal Forecast Combinations: Theory 312		
		Estimation of Forecast Combination Weights 316		
		Risk for Forecast Combinations 325		
		Model Combination 329		
		Density Combination 336		
		Bayesian Model Averaging 339		
		Empirical Evidence 341		
	14.7	Conclusion 344		
	14.0	Conclusion 344		
		III Forecast Evaluation		
15	Desir	rable Properties of Forecasts 347		
	15.1	Informal Evaluation Methods 348		
	15.2	Loss Decomposition Methods 352		
	15.3	Efficiency Properties with Known Loss 355		
		Optimality Tests under Unknown Loss 365		
		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		

12 Binary Forecasts 260

17	Evaluation and Comparison of Multiple Forecasts 391			
	17.1	Forecast Encompassing Tests 393		
	17.2	Tests of Equivalent Expected Loss. The Diebold Marients		
	17.3	Comparing Forecasting Methods: The Giacomini-White		
		Approach 400 Community Foregasting Performance across Nested Models 403		
	17.4	Comparing Forecasting Feriorinance across Nested Models		
	17.5	Comparing Many Forecasts 409		
	17.6	Addressing Data Mining 413		
		Identifying Superior Models 415		
		Choice of Sample Split 417		
		Relating the Methods 418		
		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	Forec	easting 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