# Contents

Preface xvi

**MODULE I  STATISTICS AND TIME SERIES**

**CHAPTER 1  Introduction and Context**

1.1 What Is Forecasting? 1
   1.1.1 The First Forecaster in History: The Delphi Oracle 1
   1.1.2 Examples of Modern Forecasts 2
   1.1.3 Definition of Forecasting 3
   1.1.4 Two Types of Forecasts 4
1.2 Who Are the Users of Forecasts? 4
   1.2.1 Firms 4
   1.2.2 Consumers and Investors 5
   1.2.3 Government 5
1.3 Becoming Familiar with Economic Time Series:
   Features of a Time Series 6
   1.3.1 Trends 7
   1.3.2 Cycles 8
   1.3.3 Seasonality 9
1.4 Basic Notation and the Objective of the Forecaster 11
   1.4.1 Basic Notation 11
   1.4.2 The Forecaster's Objective 12
1.5 A Road Map for This Forecasting Book 13
1.6 Resources 14

**Key Words** 16

**Exercises** 17

**CHAPTER 2  Review of the Linear Regression Model** 24

2.1 Conditional Density and Conditional Moments 24
2.2 Linear Regression Model 27
4.3.2 Examples 91
4.3.3 Optimal Forecast: An Introduction 93

Key Words 96
Appendix 97
Exercises 98

A PAUSE Where Are We and Where Are We Going? 100
Where Are We Going from Here? 100
How to Organize Your Reading of the Forthcoming Chapters 102

CHAPTER 5 Understanding Linear Dependence: A Link to Economic Models 103
5.1 Price Dynamics: The Cob-Web Model (Beginner Level) 103
  5.1.1 The Effect of Only One Supply Shock 105
  5.1.2 The Effect of Many Supply Shocks 106
  5.1.3 A Further Representation of the Dynamics in the Cob-Web Model 107
  5.1.4 Simulation of the Model, $p_t = p^* (1 - \phi) + \phi p_{t-1} + \epsilon_t$, and Autocorrelation Function 109
5.2 Portfolio Returns and Nonsynchronous Trading (Intermediate Level) 113
5.3 Asset Prices and the Bid–Ask Bounce (Advanced Level) 116
5.4 Summary 121

Key Words 121
Appendix 121
Exercises 123

CHAPTER 6 Forecasting with Moving Average (MA) Processes 125
6.1 A Model with No Dependence: White Noise 125
  6.1.1 What Does This Process Look Like? 126
6.2 The Wold Decomposition Theorem: The Origin of AR and MA Models (Advanced Section) 129
  6.2.1 Finite Representation of the Wold Decomposition 131
6.3 Forecasting with Moving Average Models 133
  6.3.1 MA(1) Process 135
  6.3.2 MA(q) Process 147

Key Words 157
Appendix 157
Exercises 158
## CHAPTER 7  Forecasting with Autoregressive (AR) Processes

7.1  Cycles  
7.2  Autoregressive Models  
7.2.1  The AR(1) Process  
7.2.2  AR(2) Process  
7.2.3  AR(p) Process  
7.2.4  Chain Rule of Forecasting  
7.3  Seasonal Cycles  
7.3.1  Deterministic and Stochastic Seasonal Cycles  
7.3.2  Seasonal ARMA Models  
7.3.3  Combining ARMA and Seasonal ARMA Models  

### Key Words
- Key Words
- Exercises

## CHAPTER 8  Forecasting Practice I

8.1  The Data: San Diego House Price Index  
8.2  Model Selection  
8.2.1  Estimation: AR, MA, and ARMA Models  
8.2.2  Is the Process Covariance-Stationary, and Is the Process Invertible?  
8.2.3  Are the Residuals White Noise?  
8.2.4  Are the Parameters of the Model Statistically Significant?  
8.2.5  Is the Model Explaining a Substantial Variation of the Variable of Interest?  
8.2.6  Is It Possible to Select One Model Among Many?  
8.3  The Forecast  
8.3.1  Who Are the Consumers of Forecasts?  
8.3.2  Is It Possible To Have Different Forecasts from the Same Model?  
8.3.3  What Is the Most Common Loss Function in Economics and Business?  
8.3.4  Final Comments  

### Key Words
- Key Words
- Exercises

## CHAPTER 9  Forecasting Practice II: Assessment of Forecasts and Combination of Forecasts

9.1  Optimal Forecast  
9.1.1  Symmetric and Asymmetric Loss Functions  
9.1.2  Testing the Optimality of the Forecast  
9.2  Assessment of Forecasts  
9.2.1  Descriptive Evaluation of the Average Loss  
9.2.2  Statistical Evaluation of the Average Loss  

### Key Words
- Key Words
- Exercises
9.3 Combination of Forecasts
   9.3.1 Simple Linear Combinations 244
   9.3.2 Optimal Linear Combinations 245

Key Words 247
Appendix 248
Exercises 250

A PAUSE Where Are We and Where Are We Going? 252

Where Are We Going from Here? 253

CHAPTER 10 Forecasting the Long Term: Deterministic and Stochastic Trends 255

10.1 Deterministic Trends
   10.1.1 Trend Shapes 258
   10.1.2 Trend Stationarity 261
   10.1.3 Optimal Forecast 262

10.2 Stochastic Trends
   10.2.1 Trend Shapes 270
   10.2.2 Stationarity Properties 272
   10.2.3 Optimal Forecast 279

Key Words 291
Exercises 291

CHAPTER 11 Forecasting with a System of Equations: Vector Autoregression 293

11.1 What Is Vector Autoregression (VAR)? 294
11.2 Estimation of VAR 294
11.3 Granger Causality 299
11.4 Impulse-Response Functions 302
11.5 Forecasting with VAR 305

Key Words 309
Exercises 309

CHAPTER 12 Forecasting the Long Term and the Short Term Jointly 311

12.1 Finding a Long-Term Equilibrium Relationship 315
12.2 Quantifying Short-Term Dynamics: Vector Error Correction Model 322
12.3 Constructing the Forecast 327

Key Words 332
Exercises 332
A PAUSE   Where Are We and Where Are We Going? 334
Where We Are Going from Here 335
How to Organize Your Reading of the Forthcoming Chapters 336

MODULE III   MODELING MORE COMPLEX DEPENDENCE

CHAPTER 13   Forecasting Volatility I 337
13.1   Motivation 337
   13.1.1   The World is Concerned About Uncertainty 337
   13.1.2   Volatility Within the Context of Our Forecasting Problem 339
   13.1.3   Setting the Objective 340
13.2   Time-Varying Dispersion: Empirical Evidence 341
13.3   Is There Time Dependence in Volatility? 345
13.4   What Have We Learned So Far? 353
13.5   Simple Specifications for the Conditional Variance 353
   13.5.1   Rolling Window Volatility 354
   13.5.2   Exponentially Weighted Moving Average (EWMA) Volatility 355

Key Words 357
Exercises 357

CHAPTER 14   Forecasting Volatility II 359
14.1   The ARCH Family 360
   14.1.1   ARCH(1) 362
   14.1.2   ARCH(p) 368
   14.1.3   GARCH(1,1) 370
   14.1.4   Estimation Issues for the ARCH Family 378
14.2   Realized Volatility 380

Key Words 390
Appendix 390
Exercises 393

CHAPTER 15   Financial Applications of Time-Varying Volatility 395
15.1   Risk Management 395
   15.1.1   Value-at-Risk (VaR) 396
   15.1.2   Expected Shortfall (ES) 400