

Neapolis University

HEPHAESTUS Repository

<http://hephaestus.nup.ac.cy>

---

School of Economic Sciences and Business

Books

---

1998

# Forecasting: Methods and Applications

Makridakis, Spyros

John Wiley & Sons, Inc.

---

<http://hdl.handle.net/11728/6636>

*Downloaded from HEPHAESTUS Repository, Neapolis University institutional repository*

# FORECASTING

---

Methods and Applications  
Third Edition

Spyros Makridakis

European Institute of Business  
Administration (INSEAD)

Steven C. Wheelwright

Harvard University, Graduate  
School of Business Administration

Rob J. Hyndman

Monash University, Department of  
Mathematics and Statistics



John Wiley & Sons, Inc.

# CONTENTS

---

## 1 / THE FORECASTING PERSPECTIVE 1

- 1/1 Why forecast? 2
- 1/2 An overview of forecasting techniques 6
  - 1/2/1 Explanatory versus time series forecasting 10
  - 1/2/2 Qualitative forecasting 12
- 1/3 The basic steps in a forecasting task 13

References and selected bibliography 17

Exercises 19

## 2 / BASIC FORECASTING TOOLS 20

- 2/1 Time series and cross-sectional data 21
- 2/2 Graphical summaries 23
  - 2/2/1 Time plots and time series patterns 24
  - 2/2/2 Seasonal plots 26
  - 2/2/3 Scatterplots 27
- 2/3 Numerical summaries 28
  - 2/3/1 Univariate statistics 29
  - 2/3/2 Bivariate statistics 34
  - 2/3/3 Autocorrelation 38
- 2/4 Measuring forecast accuracy 41
  - 2/4/1 Standard statistical measures 42
  - 2/4/2 Out-of-sample accuracy measurement 45
  - 2/4/3 Comparing forecast methods 46
  - 2/4/4 Theil's U-statistic 48
  - 2/4/5 ACF of forecast error 50

2/5 Prediction intervals 52

2/6 Least squares estimates 54

2/6/1 Discovering and describing relationships 59

2/7 Transformations and adjustments 63

2/7/1 Mathematical transformations 63

2/7/2 Calendar adjustments 67

2/7/3 Adjustments for inflation and population changes 70

Appendices 71

2-A Notation for quantitative forecasting 71

2-B Summation sign  $\Sigma$  72

References and selected bibliography 74

Exercises 76

## 3 / TIME SERIES DECOMPOSITION 81

- 3/1 Principles of decomposition 84
  - 3/1/1 Decomposition models 84
  - 3/1/2 Decomposition graphics 87
  - 3/1/3 Seasonal adjustment 88
- 3/2 Moving averages 89
  - 3/2/1 Simple moving averages 89
  - 3/2/2 Centered moving averages 94
  - 3/2/3 Double moving averages 98
  - 3/2/4 Weighted moving averages 98
- 3/3 Local regression smoothing 101
  - 3/3/1 Loess 104
- 3/4 Classical decomposition 106
  - 3/4/1 Additive decomposition 107
  - 3/4/2 Multiplicative decomposition 109

- 3/4/3 Variations on classical decomposition 112
- 3/5 Census Bureau methods 113
  - 3/5/1 First iteration 114
  - 3/5/2 Later iterations 118
  - 3/5/3 Extensions to X-12-ARIMA 119
- 3/6 STL decomposition 121
  - 3/6/1 Inner loop 122
  - 3/6/2 Outer loop 123
  - 3/6/3 Choosing the STL parameters 124
  - 3/6/4 Comparing STL with X-12-ARIMA 124
- 3/7 Forecasting and decomposition 125

References and selected bibliography 127

Exercises 130

## 4 / EXPONENTIAL SMOOTHING METHODS 135

- 4/1 The forecasting scenario 138
- 4/2 Averaging methods 141
  - 4/2/1 The mean 141
  - 4/2/2 Moving averages 142
- 4/3 Exponential smoothing methods 147
  - 4/3/1 Single exponential smoothing 147
  - 4/3/2 Single exponential smoothing: an adaptive approach 155
  - 4/3/3 Hot's linear method 158
  - 4/3/4 Holt-Winters' trend and seasonality method 161
  - 4/3/5 Exponential smoothing: Pegels' classification 169
- 4/4 A comparison of methods 171
- 4/5 General aspects of smoothing methods 174

- 4/5/1 Initialization 174
- 4/5/2 Optimization 176
- 4/5/3 Prediction intervals 177

References and selected bibliography 179

Exercises 181

## 5 / SIMPLE REGRESSION 185

- 5/1 Regression methods 186
- 5/2 Simple regression 187
  - 5/2/1 Least squares estimation 188
  - 5/2/2 The correlation coefficient 193
  - 5/2/3 Cautions in using correlation 196
  - 5/2/4 Simple regression and the correlation coefficient 198
  - 5/2/5 Residuals, outliers, and influential observations 203
  - 5/2/6 Correlation and causation 208
- 5/3 Inference and forecasting with simple regression 208
  - 5/3/1 Regression as statistical modeling 209
  - 5/3/2 The *F*-test for overall significance 211
  - 5/3/3 Confidence intervals for individual coefficients 215
  - 5/3/4 *t*-tests for individual coefficients 217
  - 5/3/5 Forecasting using the simple regression model 218
- 5/4 Non-linear relationships 221
  - 5/4/1 Non-linearity in the parameters 222
  - 5/4/2 Using logarithms to form linear models 224
  - 5/4/3 Local regression 224

Appendixes 228

- S-A Determining the values of *a* and *b* 228

References and selected  
bibliography 230

Exercises 231

## 6 / MULTIPLE REGRESSION 240

6/1 Introduction to multiple linear  
regression 241

6/1/1 Multiple regression model:  
theory and practice 248

6/1/2 Solving for the regression  
coefficients 250

6/1/3 Multiple regression and the  
coefficient of determination 251

6/1/4 The *F*-test for overall  
significance 252

6/1/5 Individual coefficients: confidence  
intervals and *t*-tests 255

6/1/6 The assumptions behind multiple  
linear regression models 259

6/2 Regression with time series 263

6/2/1 Checking independence of  
residuals 265

6/2/2 Time-related explanatory  
variables 269

6/3 Selecting variables 274

6/3/1 The long list 276

6/3/2 The short list 277

6/3/3 Best subsets regression 279

6/3/4 Stepwise regression 285

6/4 Multicollinearity 287

6/4/1 Multicollinearity when there are  
two regressors 289

6/4/2 Multicollinearity when there are  
more than two regressors 289

6/5 Multiple regression and  
forecasting 291

6/5/1 Example: cross-sectional  
regression and forecasting 292

6/5/2 Example: time series regression  
and forecasting 294

6/5/3 Recapitulation 298

6/6 Econometric models 299

6/6/1 The basis of econometric  
modeling 299

6/6/2 The advantages and drawbacks  
of econometric methods 301

Appendixes 303

6-A The Durbin-Watson statistic 303

References and selected  
bibliography 305

Exercises 306

## 7 / THE BOX-JENKINS METHODOLOGY FOR ARIMA MODELS 311

7/1 Examining correlations in times  
series data 313

7/1/1 The autocorrelation function 313

7/1/2 A white noise model 317

7/1/3 The sampling distribution of  
autocorrelations 317

7/1/4 Portmanteau tests 318

7/1/5 The partial autocorrelation  
coefficient 320

7/1/6 Recognizing seasonality in a  
time series 322

7/1/7 Example: Pigs slaughtered 322

7/2 Examining stationarity of time  
series data 324

7/2/1 Removing non-stationarity in a  
time series 326

7/2/2 A random walk model 329

7/2/3 Tests for stationarity 329

7/2/4 Seasonal differencing 331

7/2/5 Backshift notion 334

7/3 ARIMA models for times series  
data 335

7/3/1 An autoregressive model of  
order one 337

References and selected  
bibliography 440

Exercises 444

## 9 / FORECASTING THE LONG-TERM 451

9/1 Cycles versus long-term trends:  
forecasting copper prices 452

9/1/1 Forecasting IBM's sales 457

9/2 Long-term mega economic  
trends 459

9/2/1 Cycles of various durations and  
depths 461

9/2/2 Implications of extrapolating  
long-term trends 464

9/3 Analogies 466

9/3/1 The Information versus the  
Industrial Revolution 467

9/3/2 Five major inventions of the  
Industrial Revolution and their  
analogues 469

9/4 Scenario building 472

9/4/1 Businesses: gaining and/or  
maintaining competitive  
advantages 472

9/4/2 Jobs, work, and leisure time 475

9/4/3 Physical versus tele-interactions:  
extent and speed of  
acceptance 476

References and selected  
bibliography 478

Exercises 480

## 10 / JUDGMENTAL FORECASTING AND ADJUSTMENTS 482

10/1 The accuracy of judgmental  
forecasts 483

10/1/1 The accuracy of forecasts in  
financial and other markets 484

10/1/2 Non-investment type  
forecasts 490

10/2 The nature of judgmental biases  
and limitations 492

10/2/1 Judgmental biases in  
forecasting 493

10/2/2 Dealing with judgmental  
biases 496

10/2/3 Conventional wisdom 502

10/3 Combining statistical and  
judgmental forecasts 503

10/3/1 Arriving at final forecasts during  
a budget meeting 503

10/4 Conclusion 508

References and selected  
bibliography 509

Exercises 512

## 11 / THE USE OF FORECASTING METHODS IN PRACTICE 514

11/1 Surveys among forecasting  
users 515

11/1/1 Familiarity and satisfaction with  
major forecasting methods 516

11/1/2 The use of different forecasting  
methods 520

11/2 Post-sample accuracy: empirical  
findings 525

11/3 Factors influencing method  
selection 532

11/4 The combination of forecasts 537

11/4/1 Factors that contribute to making  
combining work 538

11/4/2 An example of combining 539

References and selected bibliography 543

Exercises 547

## 12 / IMPLEMENTING

FORECASTING: ITS USES, ADVANTAGES, AND LIMITATIONS 549

12/1 What can and cannot be predicted 551

12/1/1 Short-term predictions 553

12/1/2 Medium-term predictions 554

12/1/3 Long-term predictions 557

12/2 Organizational aspects of forecasting 558

12/2/1 Correcting an organization's forecasting problems 561

12/2/2 Types of forecasting problems and their solutions 562

12/3 Extrapolative predictions versus creative insights 567

12/3/1 Hindsight versus foresight 569

12/4 Forecasting in the future 571

12/4/1 Data, information, and forecasts 571

12/4/2 Collective knowledge, experience, and forecasting 572

References and selected bibliography 575

Exercises 576

## APPENDIX I / FORECASTING RESOURCES 577

I Forecasting software 578

I/1 Spreadsheets 578

I/2 Statistics packages 578

I/3 Specialty forecasting packages 579

I/4 Selecting a forecasting package 582

2 Forecasting associations 583

3 Forecasting conferences 585

4 Forecasting journals and newsletters 585

5 Forecasting on the Internet 586

References and selected bibliography 588

## APPENDIX II / GLOSSARY OF FORECASTING TERMS 589

## APPENDIX III / STATISTICAL TABLES 549

A: Normal probabilities 620

B: Critical values for  $t$ -statistic 621

C: Critical values for  $F$ -statistic 622

D: Inverse normal table 628

E: Critical values for  $\chi^2$  statistic 629

F: Values of the Durbin-Watson statistic 630

G: Normally distributed observations 632

AUTHOR INDEX 633

SUBJECT INDEX 636

## THE FORECASTING PERSPECTIVE

- I/1 Why forecast? 2
- I/2 An overview of forecasting techniques 6
  - I/2/1 Explanatory versus time series forecasting 10
  - I/2/2 Qualitative forecasting 12
- I/3 The basic steps in a forecasting task 13
- References and selected bibliography 17
- Exercises 19