

Brief Table of Contents

About the Author	ix
About the Cover	xi
Preface	xxix
I Getting Started	1
1 Introduction	3
2 Universal Considerations	21
II Cross Sections: Basics	47
3 Predictive Regression: Review and Interpretation	49
4 Forecast Model Building and Use	77
III Time Series: A Components Perspective	109
5 Trend and Seasonality	111
6 Cycles I: Autoregressions and Wold's Chain Rule	141
7 Cycles II: The Wold Representation and Its Approximation	199
8 Noise: Conditional Variance Dynamics	273

9 Assembling the Components	311
IV Forecast Evaluation and Combination	331
10 Point Forecast Evaluation	333
11 Interval and Density Forecast Evaluation	383
12 Model-Based Forecast Combination	397
13 Market-Based Forecast Combination	421
14 Survey-Based Forecast Combination	437
V More	443
15 Selection, Shrinkage, and Distillation	445
16 Multivariate: Vector Autoregression	461
VI Appendices	507
A Elements of Probability and Statistics	509
B Elements of Nonparametrics	523
C Problems and Complements Data	535
D Some Pop and “Cross-Over” Books and Sites Worth Examining	575
E Construction of the Wage Datasets	577

Detailed Table of Contents

About the Author	ix
About the Cover	xi
Preface	xxix
I Getting Started	1
1 Introduction	3
1.1 Welcome	3
1.2 Who Forecasts, and Why?	4
1.3 Useful Materials	9
1.3.1 Books	9
1.3.2 Online Information and Data	10
1.3.3 Software (and a Tiny bit of Hardware)	11
1.3.4 Journals and Professional Organizations	13
1.4 Final Thoughts	13
1.5 Tips on How to use this book	14
1.6 Exercises, Problems and Complements	17
2 Universal Considerations	21
2.1 The Forecast Object	23
2.2 The Information Set	25
2.2.1 Univariate vs. Multivariate	25
2.2.2 Expert Opinion and Judgment	26
2.2.3 Information Sets in Forecast Evaluation	26
2.3 Model Uncertainty and Improvement	27
2.4 The Forecast Horizon	27

2.4.1	<i>h</i> -Step-Ahead Forecasts	27
2.4.2	<i>h – Step</i> Ahead Path Forecasts	28
2.4.3	Nowcasting and Backcasting	28
2.5	Structural Change	30
2.6	The Forecast Statement	30
2.6.1	Time Series	30
2.6.2	Events	34
2.6.3	Probability Forecasts as Point and/or Density Forecasts	35
2.7	Forecast Presentation	35
2.7.1	Graphics for Forecasts	35
2.7.2	Graphics for Forecast Evaluation	35
2.8	The Decision Environment and Loss Function	35
2.8.1	Loss Functions	35
2.8.2	Optimal Forecasts with Respect to a Loss Function . .	37
2.8.3	State-Dependent Loss	39
2.9	Model Complexity and the Parsimony Principle	39
2.10	Unobserved Components	41
2.11	Concluding Remarks	41
2.12	Exercises, Problems and Complements	42
II	Cross Sections: Basics	47
3	Predictive Regression: Review and Interpretation	49
3.1	Regression as Curve Fitting	49
3.1.1	Simple Regression	49
3.1.2	Multiple Regression	52
3.2	Regression as a Probability Model	53
3.2.1	A Population Model and a Sample Estimator	53
3.2.2	Notation, Assumptions and Results: The Full Ideal Conditions	54
	A Bit of Matrix Notation	54
	Assumptions: The Full Ideal Conditions (FIC)	55
	Results Under the FIC	56
3.3	A Typical Regression Analysis	56
3.3.1	Coefficient Estimates, Standard Errors, <i>t</i> Statistics and <i>p</i> -Values	57

3.3.2	Residual Plot	60
3.3.3	Mean dependent var	61
3.3.4	S.D. dependent var	61
3.3.5	Sum squared resid	62
3.3.6	F-statistic	62
3.3.7	Prob(F-statistic)	63
3.3.8	S.E. of regression	63
3.3.9	R-squared	64
3.3.10	Adjusted R-squared	65
3.3.11	Durbin-Watson stat	65
3.3.12	Akaike info criterion and Schwarz criterion	66
3.3.13	Log Likelihood	67
3.4	Regression From a Forecasting Perspective	67
3.4.1	The Key to Everything (or at Least Many Things) . .	67
3.4.2	Why Take a Probabilistic Approach to Regression, as Opposed to Pure Curve Fitting?	69
3.4.3	Regression For Estimating Conditional Means is Re- gression for Forecasting	69
3.4.4	LS and Quadratic Loss	70
3.4.5	Estimated Coefficient Signs and Sizes	70
3.4.6	Standard Errors, <i>t</i> Statistics, <i>p</i> -values, <i>F</i> Statistic, Log Likelihood, etc.	70
3.4.7	Fitted Values and Residuals	70
3.4.8	Mean and Variance of Dependent Variable	71
3.4.9	R^2 and \bar{R}^2	71
3.4.10	<i>SSR</i> (or <i>MSE</i>), <i>SER</i> (or Residual s^2), <i>AIC</i> and <i>SIC</i>	72
3.4.11	Durbin-Watson	72
3.4.12	Residual Plots	73
3.5	Exercises, Problems and Complements	73
4	Forecast Model Building and Use	77
4.1	Cross-Section Prediction	77
4.1.1	Point Prediction	78
4.1.2	Density Prediction for <i>D</i> Gaussian	78
4.1.3	Density Prediction for <i>D</i> Parametric Non-Gaussian .	79
4.1.4	Making the Forecasts Feasible	79

4.1.5	Density Prediction for D Non-Parametric	80
4.1.6	Density Forecasts for D Nonparametric and Acknowledging Parameter Estimation Uncertainty	80
4.1.7	Incorporating Heteroskedasticity	81
4.2	Wage Prediction Conditional on Education and Experience . .	82
4.2.1	The CPS Dataset	82
4.2.2	Regression	84
4.2.3	Point Prediction by Exponentiating vs. Simulation . .	85
4.2.4	Density Prediction for D Gaussian	86
4.2.5	Density Forecasts for D Gaussian and Acknowledging Parameter Estimation Uncertainty	87
4.2.6	Density Forecasts for D Gaussian, Acknowledging Parameter Estimation Uncertainty, and Allowing for Heteroskedasticity	88
4.2.7	Density Prediction for D Nonparametric	92
4.2.8	Density Forecasts for D Nonparametric and Acknowledging Parameter Estimation Uncertainty	93
4.2.9	Modeling Directly in Levels	94
4.3	Non-Parametric Estimation of Conditional Mean Functions .	96
4.3.1	Global Nonparametric Regression: Series	96
	The Curse of Dimensionality	97
	Bandwidth Selection and the Bias-Variance Tradeoff .	98
4.3.2	Local Nonparametric Regression: Nearest-Neighbor . .	98
	Unweighted Locally-Constant Regression	98
	Weighted Locally-Linear Regression	99
	“Robustness Iterations”	100
4.3.3	Forecasting Perspectives	101
	On Global vs. Local Smoothers for Forecasting . . .	101
	Nearest Neighbors as a General Forecasting Method .	102
4.4	Wage Prediction, Continued	102
4.4.1	Point Wage Prediction	102
4.4.2	Density Wage Prediction	102
4.5	Exercises, Problems and Complements	102
4.6	Notes	107

III Time Series: A Components Perspective	109
5 Trend and Seasonality	111
5.1 The Forecasting the Right-Hand-Side Variables (FRV) Problem	111
5.2 Deterministic Trend	113
5.2.1 Trend Models	113
5.2.2 Trend Estimation	116
5.2.3 Forecasting Trends	118
5.2.4 Forecasting Retail Sales	120
5.3 Deterministic Seasonality	127
5.3.1 Seasonal Models	128
5.3.2 Seasonal Estimation	129
5.3.3 Forecasting Seasonals	130
5.3.4 Forecasting Housing Starts	131
5.4 Exercises, Problems and Complements	137
5.5 Notes	140
6 Cycles I: Autoregressions and Wold's Chain Rule	141
6.1 Characterizing Cycles	142
6.1.1 Covariance Stationary Time Series	142
Basic Ideas	142
6.2 White Noise	150
6.2.1 Basic Ideas	150
6.3 Estimation and Inference for the Mean, Autocorrelation and Partial Autocorrelation Functions	156
6.3.1 Sample Mean	156
6.3.2 Sample Autocorrelations	157
6.3.3 Sample Partial Autocorrelations	159
6.4 Canadian Employment I: Characterizing Cycles	161
6.5 Modeling Cycles With Autoregressions	164
6.5.1 Some Preliminary Notation: The Lag Operator	164
6.5.2 Autoregressive Processes	165
6.5.3 Autoregressive Disturbances and Lagged Dependent Variables	166
The $AR(1)$ Process for Observed Series	167
6.5.4 The $AR(p)$ Process	176
6.6 Canadian Employment II: Modeling Cycles	178

6.7	Forecasting Cycles with Autoregressions	181
6.7.1	On the FRV Problem	181
6.7.2	Information Sets, Conditional Expectations, and Linear Projections	181
6.7.3	Point Forecasts for Autoregressions: Wold's Chain Rule	183
6.7.4	Density Forecasts	184
6.8	Canadian Employment III: Forecasting	186
6.9	Exercises, Problems and Complements	190
6.10	Notes	198
7	Cycles II: The Wold Representation and Its Approximation	199
7.1	The Wold Representation and the General Linear Process . . .	199
7.1.1	The Wold Representation	199
7.1.2	The General Linear Process	201
7.2	Approximating the Wold Representation	202
7.2.1	Rational Distributed Lags	203
7.2.2	Moving Average (<i>MA</i>) Models	205
	The <i>MA</i> (1) Process	205
	The <i>MA</i> (<i>q</i>) Process	213
7.2.3	Autoregressive (<i>AR</i>) Models	215
	The <i>AR</i> (1) Process	215
	The <i>AR</i> (<i>p</i>) Process	222
7.2.4	Autoregressive Moving Average (<i>ARMA</i>) Models . . .	226
7.3	Forecasting Cycles From a Moving-Average Perspective: Wiener-Kolmogorov	228
7.3.1	Optimal Point Forecasts for Finite-Order Moving Averages	230
7.3.2	Optimal Point Forecasts for Infinite-Order Moving Averages	233
7.3.3	Interval and Density Forecasts	235
7.3.4	Making the Forecasts Operational	236
7.4	Forecasting Cycles From an Autoregressive Perspective: Wold's Chain Rule	238
7.4.1	Point Forecasts of Autoregressive Processes	238
7.4.2	Point Forecasts of ARMA processes	240
7.4.3	Interval and Density Forecasts	242

7.5	Canadian Employment	243
7.6	Exercises, Problems and Complements	264
7.7	Notes	271
8	Noise: Conditional Variance Dynamics	273
8.1	The Basic ARCH Process	274
8.2	The GARCH Process	280
8.3	Extensions of ARCH and GARCH Models	287
8.3.1	Asymmetric Response	287
8.3.2	Exogenous Variables in the Volatility Function	288
8.3.3	Regression with GARCH disturbances and GARCH-M	289
8.3.4	Component GARCH	289
8.3.5	Mixing and Matching	290
8.4	Estimating, Forecasting and Diagnosing GARCH Models . . .	290
8.5	Application: Stock Market Volatility	293
8.6	Exercises, Problems and Complements	303
8.7	Notes	309
9	Assembling the Components	311
9.1	Serially Correlated Disturbances	312
9.2	Lagged Dependent Variables	314
9.2.1	Case Study: Forecasting Liquor Sales with Deterministic Trends and Seasonals	314
9.3	Exercises, Problems and Complements	328
9.4	Notes	329
IV	Forecast Evaluation and Combination	331
10	Point Forecast Evaluation	333
10.1	Absolute Standards for Point Forecasts	333
10.1.1	Are errors zero-mean?	335
10.1.2	Are 1-step-ahead errors white noise?	335
10.1.3	Are h -step-ahead errors are at most $MA(h - 1)$? . . .	336
10.1.4	Are h -step-ahead error variances non-decreasing in h ? .	336
10.1.5	Are errors orthogonal to available information?	336
10.2	Relative Standards for Point Forecasts	338

10.2.1 Accuracy Rankings via Expected Loss	338
10.2.2 On MSE vs. MAE	341
10.2.3 Benchmark Comparisons	343
Predictive R^2	343
Theil's U-Statistic	343
10.2.4 Measures of Forecastability	344
Population Measures	345
Sample Measures	348
10.2.5 Statistical Assessment of Accuracy Rankings	349
A Motivational Example	349
The Diebold-Mariano Perspective	350
Thoughts on Assumption <i>DM</i>	352
10.3 OverSea Shipping	353
10.4 Exercises, Problems and Complements	377
10.5 Notes	382
11 Interval and Density Forecast Evaluation	383
11.1 Interval Forecast Evaluation	383
11.1.1 Absolute Standards	383
On Correct Unconditional vs. Conditional Coverage . .	383
Christoffersen's Absolute Interval Forecast Evaluation .	384
On Testing <i>iid</i> in Forecast Evaluation	385
11.1.2 Relative Standards	386
11.2 Density Forecast Evaluation	386
11.2.1 Absolute Standards	386
Theory	386
Practical Application	388
11.2.2 Additional Discussion	389
Parameter Estimation Uncertainty	389
Improving Mis-Calibrated Density Forecasts	390
Multi-Step Density Forecasts	390
11.2.3 Relative Standards	391
11.3 Stock Return Density Forecasting	391
11.3.1 A Preliminary GARCH Simulation	391
11.3.2 Daily S&P 500 Returns	394
11.4 Exercises, Problems and Complements	395

11.5 Notes	395
12 Model-Based Forecast Combination	397
12.1 Forecast Encompassing	397
12.2 Variance-Covariance Forecast Combination	399
12.2.1 Bivariate Case	399
12.2.2 General Case	402
12.3 Regression-Based Forecast Combination	402
12.3.1 Time-Varying Combining Weights	403
12.3.2 Serial Correlation	404
12.3.3 Shrinkage of Combining Weights Toward Equality . .	405
12.3.4 Nonlinear Combining Regressions	406
12.3.5 Regularized Regression for Combining Large Numbers of Forecasts	406
12.4 Application: OverSea Shipping Volume Revisited	406
12.5 On the Optimality of Equal Weights	408
12.5.1 Under Quadratic Loss	408
12.5.2 Under Minimax Loss	411
12.6 Interval Forecast Combination	415
12.7 Density Forecast Combination	415
12.7.1 Choosing Weights to Optimize a Predictive Likelihood	415
12.7.2 Choosing Weights Optimize Conditional Calibration .	415
12.8 Exercises, Problems and Complements	415
12.9 Notes	418
13 Market-Based Forecast Combination	421
13.1 Financial Markets	421
13.1.1 General Principles	422
Point Forecasts From Forward Markets	422
Point Forecasts From Futures Markets	422
Density Forecasts From Options Markets (Using Sets of Options)	423
Event Probability Forecasts From Digital Options Mar- kets	423
Density Forecasts From Digital Options Markets (Us- ing Sets of Digital Options)	423
13.1.2 More	423

Volatility Forecasts From Options Markets	423
Correlation Forecasts From Trios of Implied Volatilities	424
Skewness Forecasts From Risk Reversals	425
Inflation Forecasts From Indexed Bonds	425
Inflation Forecasts from Bond Yields	425
Bond Yield Forecasts From the Term Premium	425
Real Activity Forecasts From the Term Premium . . .	426
Real Activity Forecasts From the Default Premium . .	426
Long-Run Equity Return Forecasts from the Dividend Yield	427
13.2 “Prediction Markets”	427
13.2.1 Arrow-Debreu Contingent Claims	427
13.2.2 Parimutual Betting Markets	427
13.3 Issues with Market-Based Forecasts	427
13.3.1 Market Inefficiencies and No-Arbitrage Conditions	428
13.3.2 Moral Hazard and Market Manipulation	428
13.3.3 True Moral Issues	428
13.3.4 Risk Neutrality	428
13.3.5 Beyond Risk Neutrality	429
13.3.6 A Bit More on Market Efficiency	429
13.4 Exercises, Problems and Complements	430
13.5 Notes	432
14 Survey-Based Forecast Combination	437
14.1 Survey-Based Point Forecast Combination	437
14.1.1 Surveys and the Wisdom of Crowds	438
14.1.2 Delphi, Focus Groups, and Related Methods . .	438
14.1.3 Cross-Sectional Forecast Dispersion vs. True Uncertainty	438
14.2 Survey-Based Density Forecast Combination	439
14.3 Exercises, Problems and Complements	439
14.4 Notes	441
V More	443
15 Selection, Shrinkage, and Distillation	445
15.1 All-Subsets Model Selection I: Information Criteria	445

15.2 All-Subsets Model Selection II: Cross Validation	452
15.3 Stepwise Selection	453
15.3.1 Forward	453
15.3.2 Backward	454
15.4 One-Shot Estimation: Bayesian Shrinkage	454
15.5 One-Shot Estimation: Selection <i>and</i> Shrinkage	455
15.5.1 Penalized Estimation	455
15.5.2 The Lasso	455
Elastic Net	456
Adaptive Lasso	458
Adaptive Elastic Net	458
15.6 Distillation: Principal Components	458
15.6.1 Distilling “X Variables” into Principal Components . .	458
15.6.2 Principal Components Regression	459
15.7 Exercises, Problems and Complements	459
15.8 Notes	460
16 Multivariate: Vector Autoregression	461
16.1 Distributed Lag Models	462
16.2 Regressions with Lagged Dependent Variables, and Regressions with <i>ARMA</i> Disturbances	464
16.3 Vector Autoregressions	467
16.4 Predictive Causality	469
16.5 Impulse-Response Functions	472
16.6 Variance Decompositions	476
16.7 Application: Housing Starts and Completions	477
16.8 Exercises, Problems and Complements	493
16.9 Notes	501
VI Appendices	507
A Elements of Probability and Statistics	509
A.1 Populations: Random Variables, Distributions and Moments .	509
A.1.1 Univariate	509
A.1.2 Multivariate	512
A.2 Samples: Sample Moments	513

A.2.1	Univariate	513
A.2.2	Multivariate	516
A.3	Finite-Sample and Asymptotic Sampling Distributions of the Sample Mean	516
A.3.1	Exact Finite-Sample Results	517
A.3.2	Approximate Asymptotic Results (Under Weaker Assumptions)	518
A.4	Exercises, Problems and Complements	519
A.5	Notes	521
B	Elements of Nonparametrics	523
B.1	Density Estimation	523
B.1.1	The Basic Problem	523
B.1.2	Kernel Density Estimation	524
B.1.3	Bias-Variance Tradeoffs	525
	Inescapable Bias-Variance Tradeoff (in Practice, Fixed N)	525
	Escapable Bias-Variance Tradeoff (in Theory, $N \rightarrow \infty$)	525
	Convergence Rate	525
B.1.4	Optimal Bandwidth Choice	526
B.2	Multivariate	527
B.3	Functional Estimation	529
B.4	Local Nonparametric Regression	530
B.4.1	Kernel Regression	530
B.4.2	Nearest-Neighbor Regression	530
	Basic Nearest-Neighbor Regression	530
	Locally-Weighted Nearest-Neighbor Regression (Locally Polynomial, Non-Uniform Weighting)	531
B.5	Global Nonparametric Regression	531
B.5.1	Series (Sieve, Projection, ...)	531
B.5.2	Neural Networks	532
B.5.3	More	532
B.6	Time Series Aspects	532
B.7	Exercises, Problems and Complements	533
B.8	Notes	533

C Problems and Complements Data	535
C.1 Liquor Sales	535
C.2 Housing Starts and Completions	536
C.3 Shipping Volume	548
C.4 Hungarian Exchange Rate	565
C.5 Eurostar	568
C.6 BankWire Transfers	568
C.7 Nile.com Hits	569
C.8 Thompson Energy Investors	570
D Some Pop and “Cross-Over” Books and Sites Worth Examining	575
E Construction of the Wage Datasets	577