

Contents

Preface	vii
Acknowledgments	ix
List of Examples	xix
List of Figures	xxv
 Chapter 1. Introduction	 1
1. Role of Statistical Demography	1
2. Guide for the Reader	4
3. Statistical Notation and Preliminaries	4
 Chapter 2. Sources of Demographic Data	 9
1. Populations: Open and Closed	9
2. <i>De Facto</i> and <i>De Jure</i> Populations	11
3. Censuses and Population Registers	15
4. Lexis Diagram and Classification of Events	16
5. Register Data and Epidemiologic Studies	19
5.1. Event Histories from Registers	19
5.2. Cohort and Case-Control Studies	19
5.3. Advantages and Disadvantages	20
5.4. Confounding	22
6. Sampling in Censuses and Dual System Estimation	24
Exercises and Complements	27
 Chapter 3. Sampling Designs and Inference	 31
1. Simple Random Sampling	32
2. Subgroups and Ratios	35
3. Stratified Sampling	36
3.1. Introduction	36
3.2. Stratified Simple Random Sampling	37
3.3. Design Effect for Stratified Simple Random Sampling	38
3.4. Poststratification	39
4. Sampling Weights	40
4.1. Why Weight?	40

4.2. Forming Weights	41
4.3. Non-Response Adjustments	43
4.4. Effect of Weighting on Precision	45
5. Cluster Sampling	46
5.1. Introduction	46
5.2. Single Stage Sampling with Replacement	47
5.3. Single Stage Sampling without Replacement	47
5.4. Multi-Stage Sampling	49
5.5. Stratified Samples	50
6. Systematic Sampling	52
7. Distribution Theory for Sampling	53
7.1. Central Limit Theorems	53
7.2. The Delta Method	55
7.3. Estimating Equations	56
8. Replication Estimates of Variance	61
8.1. Jackknife Estimates	61
8.2. Bootstrap Estimates	62
8.3. Replication Weights	63
Exercises and Complements	64
Chapter 4. Waiting Times and Their Statistical Estimation	71
1. Exponential Distribution	71
2. General Waiting Time	76
2.1. Hazards and Survival Probabilities	76
2.2. Life Expectancies and Stable Populations	79
2.2.1. Life Expectancy	79
2.2.2. Life Table Populations and Stable Populations	81
2.2.3. Changing Mortality	82
2.2.4. Basics of Pension Funding	84
2.2.5. Effect of Heterogeneity	85
2.3. Kaplan-Meier and Nelson-Aalen Estimators	85
2.4. Estimation Based on Occurrence-Exposure Rates	88
3. Estimating Survival Proportions	91
4. Childbearing as a Repeatable Event	93
4.1. Poisson Process Model of Childbearing	93
4.2. Summary Measures of Fertility and Reproduction	96
4.3. Period and Cohort Fertility	101
4.3.1. Cohort Fertility is Smoother	101
4.3.2. Adjusting for Timing	103
4.3.3. Effect of Parity on Pure Period Measures	104
4.4. Multiple Births and Effect of Pregnancy on Exposure Time	106
5. Poisson Character of Demographic Events	107
6. Simulation of Waiting Times and Counts	109
Exercises and Complements	110

Chapter 5. Regression Models for Counts and Survival	117
1. Generalized Linear Models	118
1.1. Exponential Family	118
1.2. Use of Explanatory Variables	119
1.3. Maximum Likelihood Estimation	119
1.4. Numerical Solution	120
1.5. Inferences	121
1.6. Diagnostic Checks	122
2. Binary Regression	123
2.1. Interpretation of Parameters and Goodness of Fit	123
2.2. Examples of Logistic Regression	124
2.3. Applicability in Case-Control Studies	129
3. Poisson Regression	130
3.1. Interpretation of Parameters	130
3.2. Examples of Poisson Regression	131
3.3. Standardization	133
3.4. Loglinear Models for Capture-Recapture Data	136
4. Overdispersion and Random Effects	138
4.1. Direct Estimation of Overdispersion	139
4.2. Marginal Models for Overdispersion	139
4.3. Random Effect Models	140
5. Observable Heterogeneity in Capture-Recapture Studies	143
6. Bilinear Models	146
7. Proportional Hazards Models for Survival	150
8. Heterogeneity and Selection by Survival	154
9. Estimation of Population Density	156
10. Simulation of the Regression Models	158
Exercises and Complements	159
Chapter 6. Multistate Models and Cohort-Component Book-Keeping	166
1. Multistate Life-Tables	167
1.1. Numerical Solution Using Runge-Kutta Algorithm	167
1.2. Extension to Multistate Case	168
1.3. Duration-Dependent Life-Tables	172
1.3.1. Heterogeneity Attributable to Duration	172
1.3.2. Forms of Duration-Dependence	173
1.3.3. Aspects of Computer Implementation	174
1.3.4. Policy Significance of Duration-Dependence	175
1.4. Nonparametric Intensity Estimation	175
1.5. Analysis of Nuptiality	177
1.6. A Model for Disability Insurance	179
2. Linear Growth Model	180
2.1. Matrix Formulation	180

2.2. Stable Populations	183
2.3. Weak Ergodicity	185
3. Open Populations and Parametrization of Migration	186
3.1. Open Population Systems	186
3.2. Parametric Models	186
3.2.1. Migrant Pool Model	187
3.2.2. Bilinear Models	187
4. Demographic Functionals	189
5. Elementwise Aspects of the Matrix Formulation	191
6. Markov Chain Models	191
Exercises and Complements	193
Chapter 7. Approaches to Forecasting Demographic Rates	198
1. Trends, Random Walks, and Volatility	198
2. Linear Stationary Processes	201
2.1. Properties and Modeling	202
2.1.1. Definition and Basic Properties	202
2.1.2. ARIMA Models	203
2.1.3. Practical Modeling	206
2.2. Characterization of Predictions and Prediction Errors	210
2.2.1. Stationary Processes	210
2.2.2. Integrated Processes	211
2.2.3. Cross-Correlations	216
3. Handling of Nonconstant Mean	216
3.1. Differencing	216
3.2. Regression	218
3.3. Structural Models	219
4. Heteroscedastic Innovations	220
4.1. Deterministic Models of Volatility	221
4.2. Stochastic Volatility	222
Exercises and Complements	223
Chapter 8. Uncertainty in Demographic Forecasts: Concepts, Issues, and Evidence	226
1. Historical Aspects of Cohort-Component Forecasting	228
1.1. Adoption of the Cohort-Component Approach	228
1.2. Whelpton's Legacy	228
1.3. Do We Know Better Now?	231
2. Dimensionality Reduction for Mortality	234
2.1. Age-Specific Mortality	234
2.2. Cause-Specific Mortality	236
3. Conceptual Aspects of Error Analysis	238
3.1. Expected Error and Empirical Error	238
3.2. Decomposing Errors	238
3.2.1. Error Classifications	238
3.2.2. Alternative Decompositions	240

3.3. Acknowledging Model Error	240
3.3.1. Classes of Parametric Models	240
3.3.2. Data Period Bias	241
3.4. Feedback Effects of Forecasts	242
3.5. Interpretation of Prediction Intervals	244
3.5.1. Uncertainty in Terms of Subjective Probabilities	244
3.5.2. Frequency Properties of Prediction Intervals	248
3.6. Role of Judgment	249
3.6.1. Expert Arguments	249
3.6.2. Scenarios	250
3.6.3. Conditional Forecasts	251
4. Practical Error Assessment	251
4.1. Error Measures	252
4.2. Baseline Forecasts	253
4.3. Modeling Errors in World Forecasts	256
4.3.1. An Error Model for Growth Rates	256
4.3.2. Second Moments	257
4.3.3. Predictive Distributions for Countries and the World	259
4.4. Random Jump-off Values	261
4.4.1. Jump-off Population	262
4.4.2. Mortality	263
5. Measuring Correlatedness	264
Exercises and Complements	267
Chapter 9. Statistical Propagation of Error in Forecasting	269
1. Törnqvist's Contribution	269
2. Predictive Distributions	271
2.1. Regression with a Known Covariance Structure	271
2.2. Random Walks	274
2.3. ARIMA(1,1,0) Models	276
3. Forecast as a Database and Its Uses	277
4. Parametrizations of Covariance Structure	278
4.1. Effect of Correlations on the Variance of a Sum	279
4.2. Scaled Model for Error	280
4.3. Structure of Error in Migration Forecasts	283
5. Analytical Propagation of Error	284
5.1. Births	284
5.2. General Linear Growth	285
6. Simulation Approach and Computer Implementation	287
7. Post Processing	289
7.1. Altering a Distributional Form	289
7.2. Creating Correlated Populations	292
7.2.1. Use of Seeds	292
7.2.2. Sorting Techniques	293
Exercises and Complements	294

Chapter 10. Errors in Census Numbers	296
1. Introduction	296
2. Effects of Errors on Estimates and Forecasts	297
2.1. Effects on Mortality Rates	297
2.2. Effects on Forecasts	298
2.3. Effects on Evaluation of Past Population Forecasts	298
3. Use of Demographic Analysis to Assess Error in U.S. Censuses	299
4. Assessment of Dual System Estimates of Population Size	300
5. Decomposition of Error in the Dual System Estimator	303
5.1. A Probability Model for the Census	303
5.2. Poststratification	304
5.3. Overview of Error Components	305
5.4. Data Error Bias	308
5.5. Decomposition of Model Bias	309
5.5.1. Synthetic Estimation Bias and Correlation Bias	309
5.5.2. Poststratified Estimator	310
5.6. Estimation of Correlation Bias in a Poststratified Dual System Estimator	312
5.7. Estimation of Synthetic Estimation Bias in a Poststratified Dual System Estimator	314
6. Assessment of Error in Functions of Dual System Estimators and Functions of Census Counts	316
6.1. Overview	316
6.2. Computation	317
Exercises and Complements	319
Chapter 11. Financial Applications	327
1. Predictive Distribution of Adjustment for Life Expectancy Change	327
1.1. Adjustment Factor for Mortality Change	327
1.2. Sampling Variation in Pension Adjustment Factors	329
1.3. The Predictive Distribution of the Pension Adjustment Factor	330
2. Fertility Dependent Pension Benefits	332
3. Measuring Sustainability	335
4. State Aid to Municipalities	337
5. Public Liabilities	339
5.1. Economic Series	340
5.2. Wealth in Terms of Random Returns and Discounting	340
5.3. Random Public Liability	341
Exercises and Complements	342
Chapter 12. Decision Analysis and Small Area Estimates	344
1. Introduction	344
2. Small Area Analysis	345

3.	Formula-Based Allocations	346
3.1.	Theoretical Construction	346
3.1.1.	Apportionment of the U.S. House of Representatives	347
3.1.2.	Rationale Behind Allocation Formulas	348
3.2.	Effect of Inaccurate Demographic Statistics	349
3.3.	Beyond Accuracy	350
4.	Decision Theory and Loss Functions	351
4.1.	Introduction	351
4.2.	Decision Theory for Statistical Agencies	353
4.3.	Loss Functions for Small Area Estimates	357
4.4.	Loss Functions for Apportionment and Redistricting	359
4.1.1.	Apportionment	359
4.1.2.	Redistricting	360
4.5.	Loss Functions and Allocation of Funds	361
4.5.1.	Effects of Over- and Under-Allocation	361
4.5.2.	Formula Nonoptimality	362
4.5.3.	Optimal Data Quality with Multiple Statistics and Uses	363
5.	Comparing Risks of Adjusted and Unadjusted Census Estimates	363
5.1.	Accounting for Variances of Bias Estimates	364
5.2.	Effect of Unmeasured Biases on Comparisons of Accuracy	365
6.	Decision Analysis of Adjustment for Census Undercount	365
7.	Cost-Benefit Analysis of Demographic Data Exercises and Complements	367
		368
	References	371
	Author Index	397
	Subject Index	405