

Contents

List of Tables	xvii	
List of Figures	xix	
V	Models for categorical responses	499
10	Dichotomous or binary responses	501
10.1	Introduction	501
10.2	Single-level logit and probit regression models for dichotomous responses	501
10.2.1	Generalized linear model formulation	502
10.2.2	Latent-response formulation	510
	Logistic regression	512
	Probit regression	512
10.3	Which treatment is best for toenail infection?	515
10.4	Longitudinal data structure	515
10.5	Proportions and fitted population-averaged or marginal probabilities	517
10.6	Random-intercept logistic regression	520
10.6.1	Model specification	520
	Reduced-form specification	520
	Two-stage formulation	522
10.7	Estimation of random-intercept logistic models	523
10.7.1	Using xtlogit	523
10.7.2	Using xtmelogit	527
10.7.3	Using gllamm	527
10.8	Subject-specific or conditional vs. population-averaged or marginal relationships	529

10.9	Measures of dependence and heterogeneity	532
10.9.1	Conditional or residual intraclass correlation of the latent responses	532
10.9.2	Median odds ratio	533
10.9.3	❖ Measures of association for observed responses at median fixed part of the model	533
10.10	Inference for random-intercept logistic models	535
10.10.1	Tests and confidence intervals for odds ratios	535
10.10.2	Tests of variance components	536
10.11	Maximum likelihood estimation	537
10.11.1	❖ Adaptive quadrature	537
10.11.2	Some speed and accuracy considerations	540
	Advice for speeding up estimation in glamm	542
10.12	Assigning values to random effects	543
10.12.1	Maximum “likelihood” estimation	544
10.12.2	Empirical Bayes prediction	545
10.12.3	Empirical Bayes modal prediction	546
10.13	Different kinds of predicted probabilities	548
10.13.1	Predicted population-averaged or marginal probabilities	548
10.13.2	Predicted subject-specific probabilities	549
	Predictions for hypothetical subjects: Conditional probabilities	549
	Predictions for the subjects in the sample: Posterior mean probabilities	551
10.14	Other approaches to clustered dichotomous data	557
10.14.1	Conditional logistic regression	557
10.14.2	Generalized estimating equations (GEE)	559
10.15	Summary and further reading	562
10.16	Exercises	563
11	Ordinal responses	575
11.1	Introduction	575

11.2	Single-level cumulative models for ordinal responses	575
11.2.1	Generalized linear model formulation	575
11.2.2	Latent-response formulation	576
11.2.3	Proportional odds	580
11.2.4	❖ Identification	582
11.3	Are antipsychotic drugs effective for patients with schizophrenia? .	585
11.4	Longitudinal data structure and graphs	585
11.4.1	Longitudinal data structure	586
11.4.2	Plotting cumulative proportions	587
11.4.3	Plotting cumulative sample logits and transforming the time scale	588
11.5	A single-level proportional odds model	590
11.5.1	Model specification	590
11.5.2	Estimation using Stata	591
11.6	A random-intercept proportional odds model	594
11.6.1	Model specification	594
11.6.2	Estimation using Stata	594
11.6.3	Measures of dependence and heterogeneity	595
	Residual intraclass correlation of latent responses	595
	Median odds ratio	596
11.7	A random-coefficient proportional odds model	596
11.7.1	Model specification	596
11.7.2	Estimation using gllamm	596
11.8	Different kinds of predicted probabilities	599
11.8.1	Predicted population-averaged or marginal probabilities . .	599
11.8.2	Predicted subject-specific probabilities: Posterior mean . .	602
11.9	Do experts differ in their grading of student essays?	606
11.10	A random-intercept probit model with grader bias	606
11.10.1	Model specification	606
11.10.2	Estimation using gllamm	607

11.11	Including grader-specific measurement error variances	608
11.11.1	Model specification	608
11.11.2	Estimation using gllamm	609
11.12	❖ Including grader-specific thresholds	611
11.12.1	Model specification	611
11.12.2	Estimation using gllamm	611
11.13	❖ Other link functions	616
	Cumulative complementary log-log model	616
	Continuation-ratio logit model	616
	Adjacent-category logit model	618
	Baseline-category logit and stereotype models	618
11.14	Summary and further reading	619
11.15	Exercises	620
12	Nominal responses and discrete choice	629
12.1	Introduction	629
12.2	Single-level models for nominal responses	630
12.2.1	Multinomial logit models	630
12.2.2	Conditional logit models	638
	Classical conditional logit models	639
	Conditional logit models also including covariates that vary only over units	645
12.3	Independence from irrelevant alternatives	648
12.4	Utility-maximization formulation	649
12.5	Does marketing affect choice of yogurt?	651
12.6	Single-level conditional logit models	653
12.6.1	Conditional logit models with alternative-specific intercepts	654
12.7	Multilevel conditional logit models	659
12.7.1	Preference heterogeneity: Brand-specific random intercepts	659

12.7.2	Response heterogeneity: Marketing variables with random coefficients	663
12.7.3	❖ Preference and response heterogeneity	666
	Estimation using gllamm	667
	Estimation using mixlogit	669
12.8	Prediction of random effects and response probabilities	672
12.9	Summary and further reading	676
12.10	Exercises	677
VI	Models for counts	685
13	Counts	687
13.1	Introduction	687
13.2	What are counts?	687
13.2.1	Counts versus proportions	687
13.2.2	Counts as aggregated event-history data	688
13.3	Single-level Poisson models for counts	689
13.4	Did the German health-care reform reduce the number of doctor visits?	691
13.5	Longitudinal data structure	691
13.6	Single-level Poisson regression	692
13.6.1	Model specification	692
13.6.2	Estimation using Stata	693
13.7	Random-intercept Poisson regression	696
13.7.1	Model specification	696
13.7.2	Measures of dependence and heterogeneity	697
13.7.3	Estimation using Stata	697
	Using xtpoisson	697
	Using xtmeipoisson	699
	Using gllamm	700
13.8	Random-coefficient Poisson regression	701
13.8.1	Model specification	701

13.8.2	Estimation using Stata	702
	Using xtmepoisson	702
	Using gllamm	704
13.8.3	Interpretation of estimates	705
13.9	Overdispersion in single-level models	706
13.9.1	Normally distributed random intercept	706
13.9.2	Negative binomial models	707
	Mean dispersion or NB2	708
	Constant dispersion or NB1	709
13.9.3	Quasilikelihood	709
13.10	Level-1 overdispersion in two-level models	711
13.11	Other approaches to two-level count data	713
13.11.1	Conditional Poisson regression	713
13.11.2	Conditional negative binomial regression	715
13.11.3	Generalized estimating equations	715
13.12	Marginal and conditional effects when responses are MAR	716
	❖ Simulation	717
13.13	Which Scottish counties have a high risk of lip cancer?	720
13.14	Standardized mortality ratios	721
13.15	Random-intercept Poisson regression	723
13.15.1	Model specification	723
13.15.2	Estimation using gllamm	724
13.15.3	Prediction of standardized mortality ratios	725
13.16	❖ Nonparametric maximum likelihood estimation	727
13.16.1	Specification	727
13.16.2	Estimation using gllamm	727
13.16.3	Prediction	732
13.17	Summary and further reading	732
13.18	Exercises	733

VII	Models for survival or duration data	741
	Introduction to models for survival or duration data (part VII)	743
14	Discrete-time survival	749
14.1	Introduction	749
14.2	Single-level models for discrete-time survival data	749
14.2.1	Discrete-time hazard and discrete-time survival	749
14.2.2	Data expansion for discrete-time survival analysis	752
14.2.3	Estimation via regression models for dichotomous responses	754
14.2.4	Including covariates	758
Time-constant covariates		758
Time-varying covariates		762
14.2.5	Multiple absorbing events and competing risks	767
14.2.6	Handling left-truncated data	772
14.3	How does birth history affect child mortality?	773
14.4	Data expansion	774
14.5	❖ Proportional hazards and interval-censoring	776
14.6	Complementary log-log models	777
14.7	A random-intercept complementary log-log model	781
14.7.1	Model specification	781
14.7.2	Estimation using Stata	782
14.8	❖ Population-averaged or marginal vs. subject-specific or conditional survival probabilities	784
14.9	Summary and further reading	788
14.10	Exercises	789
15	Continuous-time survival	797
15.1	Introduction	797
15.2	What makes marriages fail?	797
15.3	Hazards and survival	799
15.4	Proportional hazards models	805
15.4.1	Piecewise exponential model	807

15.4.2	Cox regression model	815
15.4.3	Poisson regression with smooth baseline hazard	819
15.5	Accelerated failure-time models	823
15.5.1	Log-normal model	824
15.6	Time-varying covariates	829
15.7	Does nitrate reduce the risk of angina pectoris?	832
15.8	Marginal modeling	835
15.8.1	Cox regression	835
15.8.2	Poisson regression with smooth baseline hazard	838
15.9	Multilevel proportional hazards models	841
15.9.1	Cox regression with gamma shared frailty	841
15.9.2	Poisson regression with normal random intercepts	845
15.9.3	Poisson regression with normal random intercept and random coefficient	847
15.10	Multilevel accelerated failure-time models	849
15.10.1	Log-normal model with gamma shared frailty	849
15.10.2	Log-normal model with log-normal shared frailty	850
15.11	A fixed-effects approach	851
15.11.1	Cox regression with subject-specific baseline hazards	851
15.12	Different approaches to recurrent-event data	853
15.12.1	Total time	854
15.12.2	Counting process	858
15.12.3	Gap time	859
15.13	Summary and further reading	861
15.14	Exercises	862
VIII	Models with nested and crossed random effects	871
16	Models with nested and crossed random effects	873
16.1	Introduction	873
16.2	Did the Guatemalan immunization campaign work?	873
16.3	A three-level random-intercept logistic regression model	875

16.3.1	Model specification	876
16.3.2	Measures of dependence and heterogeneity	876
	Types of residual intraclass correlations of the latent re- sponses	876
	Types of median odds ratios	877
16.3.3	Three-stage formulation	877
16.4	Estimation of three-level random-intercept logistic regression models	878
16.4.1	Using <code>gllamm</code>	878
16.4.2	Using <code>xtmelogit</code>	883
16.5	A three-level random-coefficient logistic regression model	886
16.6	Estimation of three-level random-coefficient logistic regression models	887
16.6.1	Using <code>gllamm</code>	887
16.6.2	Using <code>xtmelogit</code>	890
16.7	Prediction of random effects	892
16.7.1	Empirical Bayes prediction	892
16.7.2	Empirical Bayes modal prediction	893
16.8	Different kinds of predicted probabilities	894
16.8.1	Predicted population-averaged or marginal probabilities: New clusters	894
16.8.2	Predicted median or conditional probabilities	895
16.8.3	Predicted posterior mean probabilities: Existing clusters	896
16.9	Do salamanders from different populations mate successfully?	897
16.10	Crossed random-effects logistic regression	900
16.11	Summary and further reading	907
16.12	Exercises	908
A	Syntax for <code>gllamm</code>, <code>eq</code>, and <code>gllapred</code>: The bare essentials	915
B	Syntax for <code>gllamm</code>	921
C	Syntax for <code>gllapred</code>	933
D	Syntax for <code>gllasim</code>	937

References	941
Author index	955
Subject index	963