

Index

- adjacency matrix, 263, 266, 274
 asymptotic covariance matrix, 246, 256
- backward elimination, 76
 baseline choice, *see* reference category
 baseline hazard, 476, 497
 Bayes' theorem, 336
 Bayesian approach for mixed models, 411
 Bayesian credible intervals, 255
 best linear unbiased predictor (BLUP), 197, 222
 bootstrap, 465
- case control, 162
 check function, 254
 claim frequency, 273
 claim severity, 275
 average claim size, 269–271, 276
 individual claim size, 275–276
 claims payment process, 517
 classification table, 74
 coefficient of determination, *see* R^2
 collinearity, 18, 27, 30, 32, 51
 VIF, 30, 32
 conditional mean, 251
 conditional quantile, 253
 conditionally autoregressive model, *see* spatial
 autoregression
 confidence intervals, 316
 contagion, true and apparent, 97
 covariance matrix, 192
 autoregressive, 193
 diagonal, 193
 nondiagonal, 193
 Toeplitz, 193
 unstructured, 193
 covariates, 529
 time-varying, 529
 credibility, 173, 217, 334
 Bühlmann model, 207, 220
 Bühlmann-Straub model, 208, 221
 Hachemeister model, 221
 multidimensional, 189
 robust, 229
 shrinkage estimator, 198
- data
 clustered, 180, 183
 count, 87
 cross-classified, 190
 cross-sectional, 183
 grouped, 146
 hierarchical, 183, 188
 individual, 146
 longitudinal, 167, 219
 missing, 180
 multilevel, 180, 183
 nested, *see also* hierarchical
 non-Gaussian, 399
 non-nested, *see* cross-classified
 panel, 167, 183, 534
 spatial, 261
 survival, 482
 time series, 427
 transitions, 515, 522
 two-part, 141
 unbalanced, 171, 180
- data example
 Annual Flow of the River Nile, 429
 Australian Automobile Bodily Injury Scheme, 469
 Australian Workers' Compensation Insurance, 475
 Automobile PIP Questionable Claims Data, 284
 California Auto Assigned Risk (CAARP) Data,
 284
 Credit Insurance Data, 190, 212
 Cross Selling, 122
 German Car Insurance Data, 262, 269, 276
 Group Term Life, 175
 Hachemeister Data, 187, 206, 218, 224
 Heart Disease Data, 373, 390, 394
 Losses and Expenses, 142
 Massachusetts Automobile Claims, 152, 242
 Medical Expenditure Panel Survey (MEPS), 15, 247,
 254
 Mexican Central Bank, 346, 353, 356

- data example (*cont.*)
- Mexico Insurance Market, 342, 361
 - Monthly Global Temperature, 429
 - Motor Insurance, 69, 74, 80, 83
 - National Nursing Home Survey (NNHS), 482, 486, 513
 - pension plan terminations, 526, 529, 533
 - Personal Automobile Claims, 316
 - Quarterly Earnings of Johnson & Johnson, 429
 - Sales Data from Box–Jenkins, 429
 - Singapore Automobile Claims, 91
 - Texas Closed Claim Data, 284
 - U.S. Medical Malpractice Insurance, 475, 476
 - U.S. Workers' Compensation Insurance, 187, 190, 201, 412
- dependent lifetimes
- common shock, 516
- dimension reduction, 282
- distribution tail
- criteria of subexponential, 238
 - left tail, 238
 - right tail, 237
 - tail heaviness, 237
- distributions
- F -, 244
 - asymmetric Laplace, 254
 - Bernoulli, 66
 - beta prime, *see* generalized beta of the second kind (*GB2*)
 - binomial, 88, 112, 133
 - bivariate normal, 170
 - Burr XII, 245
 - exponential, 507
 - exponential *GB2*, 245
 - exponential family, 110, 146, 161, 238, 241
 - extreme value, 533
 - fat-tailed distributions, 237
 - gamma, 100, 112, 134, 146, 237, 242, 245
 - generalized beta, *see* generalized beta of the second kind (*GB2*)
 - generalized beta of the second kind (*GB2*), 244
 - generalized gamma, 245
 - geometric, 94
 - inverse-Gaussian, 100, 112, 242
 - Laplace, 252
 - location-scale, 227
 - log location-scale family, 244
 - log-normal, 100, 245
 - logistic, 507, 533
 - negative binomial, 93
 - negative binomial p (*NB p*), 93
 - normal, 21, 112, 237, 533
 - over-dispersed Poisson (*ODP*), 454
 - Pareto, 161, 237, 244, 245
 - Poisson, 87, 111
 - Poisson-inverse Gaussian, 94
 - Poisson-lognormal, 95
 - Tweedie, 128, 150
 - Weibull, 228, 237, 245, 507, 533
 - zero-inflated, 102
 - zero-inflated Poisson (*ZIP*), 102
- estimation
- corrected adaptively truncated likelihood (*CATL*), 228
 - generalized least squares (*GLS*), 196
 - Laplace method, 404
 - least absolute deviations (*LAD*), 251
 - least squares, 21, 241
 - maximum likelihood, 7, 70, 72, 90, 93, 95, 110, 118, 135, 149, 177, 241, 527, 528, 534
 - minimum bias technique, 6, 87
 - penalized least-square, 387
 - penalized quasi-likelihood (*PQL*), 406
 - pseudo-likelihood (*PL*), 406
 - restricted maximum likelihood (*REML*), 199, 219, 228
 - restricted pseudo-likelihood (*REPL*), 406
 - robust, 228
- exchangeability, 355, 356
- expected utility, 336
- exposure, 102, 144, 187, 221
- false negative, 75
- false positive, 75
- Fisher information matrix, 246, 256
- full conditional distribution, 265
- Gelman-Rubin statistic, 322
- generalized estimating equation (*GEE*), 399
- generalized linear mixed model (*GLMM*), 400
- generalized linear model (*GLM*), 7, 60, 107, 141, 238, 241, 338, 369, 399, 455, 462
- gamma regression, 117, 126, 150, 241, 249, 275–276
 - linear model, 338
 - link function, 68, 90, 109, 142, 369, 399
 - logistic regression, 67, 149, 345
 - mixed, 179
 - offset, 124, 142
 - Poisson regression, 89, 150, 241, 274, 352
 - probit regression, 78
 - systematic component, 369
 - Tweedie, 128, 150
- goodness-of-fit statistic, 75, 243
- generalized cross-validation (*GCV*), 383
- adjusted R^2 , 32, 33, 42
 - mean squared error, 381
 - predictive squared error, 382
 - pseudo- R squared, 76
 - R^2 , 25, 30, 33, 52
- hypothesis testing, 316
- influential point
- Cook's distance, 40, 41, 42
 - leverage, 34, 36
 - outlier, 34, 36, 37, 38, 40
- information statistic
- Akaike information criterion, *AIC*, 32, 33, 42, 52, 98, 132, 250, 383
 - Akaike information criterion, corrected, *AICC*, 132
 - Bayesian information criterion, *BIC*, 98, 132, 250

- deviance information criterion, *DIC*, 277, 342, 348, 393
 Kullback-Leibler, 241
 Schwarz Bayesian criterion
 see Akaike information criterion, *AIC*, 132
- Kolmogorov forward differential equations, 521
 numerical solution using Euler's method, 521
- learning
 supervised, 280
 unsupervised, 281
- life annuity and insurance, 516
- log-odds, 68
- logistic regression, *see* generalized linear model (GLM)
- logit, 68, 390
- loss reserving, 3, 399, 450
 chain ladder algorithm, 453
 generalized linear model (GLM), 455
 models of individual claims, 467
 over-dispersed Poisson (ODP) cross-classified model, 454, 463
 over-dispersed Poisson (ODP) Mack model, 454
- MSE*, *see* residual variance
- Markov chain Monte Carlo, 320
 Gibbs sampler, 320
 Metropolis-Hastings sampler, 320
- Markov chain Monte Carlo methods, 267, 276
- Markov process, 518
- Markov random field, 265
- median regression, 360
- medoid, 301
- meta-analysis, 356
- model
 GB2 regression, 244, 245, 249
 accelerated failure times, 532, 533
 Bayesian approach for median regression, 252
 Bayesian quantile regression, 254
 Burr XII regression, 249
 cluster analysis, 283
 complete pooling, 183, 201
 conditional logit, 81, 84
 cross-sectional, 182
 cumulative logit, 79
 factor analysis, 283
 frequency-severity, 148
 generalized additive model (GAM), 60, 242, 369, 388, 456
 generalized logit, 81
 hierarchical, 185, 273, 355
 inverse-Gaussian regression, 249
 linear fixed effects, 173, 183
 linear mixed (LMM), 182, 183, 184, 192, 220
 linear probability, 67
 linear random effects, 173, 183
 MCMC, *see* Markov chain Monte Carlo
 mean regression, 236
 median regression, 238, 250
 mixed, 354
 multilevel, 184, 185
 multinomial logistic regression, 83
 multinomial logit, 81, 180
 no pooling, 183, 202
 nominal categorical dependent variable, 81
 non-nested, 185
 nonlinear growth curve, 191
 nonparametric, 523
 parametric, 527, 533
 penalized splines (P-splines), 214
 principal components, 283
 proportional hazards, 529, 533
 quantile models, 251
 quantile regression, 238, 253
 random intercepts, 173, 203
 random intercepts and slopes, 205
 semi-parametric regression, 214
 Tobit, 149
 two-part, 241
 variance components, 186
 varying intercepts, 184
 varying slopes and intercepts, 184
- multistate model, 516
 absorbing state, 516
 illness-death, 517, 524, 528, 534
 multiple decrement, 517
- multiple correlation coefficient, 25
- natural parameter, 341
- Newton optimization, 72
- nonlinear mixed model (NLMM), 411
- nonparametric regression, 358, 370
 backfitting algorithm, 383
 bandwidth, 372
 cubic smoothing splines, 378
 curse of dimensionality, 369
 kernel smoother, 374
 knots, 378
 locally weighted running-line smoother (LOESS), 373
 multivariate additive models, 383
 smoother, 370, 371
- nuisance parameters, 337
- odds, 68
- odds-ratio, 69, 163
- offset, 146, 458
- out-of-sample comparisons, 158
- out-of-sample statistic
 PRESS, 42, 43
 SSPE, 42, 43
 forecast error, 464
 mean squared error of prediction (MSEP), 465
 model MSEP, 465, 466
 parameter MSEP, 465, 466
 process MSEP, 465, 466
- over-dispersion, 102, 261, 352, 454
- parameter
 location, 244, 245, 246, 253
 scale, 146, 244, 245
 shape, 244

- plot
 LOESS curve, 38
 ggplot2 package, 182
 boxplot, 19
 gains chart, 58
 Gelman-Rubin, 324
 icycle, 308
 multiple time series, 218
 quantile-quantile (QQ), 39, 247, 249
 receiver operating characteristic (ROC) curve, 77
 residual, 36
 rug, 243
 scatterplot, 16
 scatterplot matrix, 49
 scree, 293
 time series, 427, 429
 trace, 324
 trellis, 175, 187
- Poisson regression, *see* generalized linear model (GLM)
- Polya tree, 344
- posterior distribution, 253, 317
- posterior predictive, 337, 349, 350
 checks, 349, 350
- prior
 conjugate, 253, 337, 340
 degrees of belief, 335
 diffuse, 337, 341, 346, 348, 350
 hierarchical, 334, 355, 356
 improper uninformative, 253
 informative, 335, 357
 nonparametric, 344, 359
 Polya tree, 359, 362
 vague, 253, 338, 341, 343, 346, 348, 350, 353
- prior distribution, 253, 317
 conjugate, 318
 elicitation, 326
 Jeffreys', 328
 non-informative, 327
- probit regression model, *see* generalized linear model (GLM)
- proper distribution, 267, 274
- proportional hazards
 assumption, 494, 497
 baseline survival function, 501
 model, 497
 model residuals, 502
 time-varying covariates, 506
- proportional hazards model, 476
- pure premium, 127, 155
- random effect
 spatial, 274
- random effects
 binary outcomes, 177
 crossed random effects, 196
 generalized linear mixed model
see generalized linear model (GLM) 180
 intercepts, 173
 multiple random effects per level, 195
 nested random effects, 196
 single random effect per level, 195
- ratemaking, 3, 128, 133, 140, 147, 167, 222, 250, 399
 credibility, 5, 182, 187
- receiver operating characteristic (ROC), 77
- reference category, 17, 66
- regression quantile, 254
- relativity, 90, 142
- residual, 16, 22, 28, 36, 37, 53, 218, 228, 247
 MSE, 26
 Cox-Snell, 502
 deviance, 503
 deviance residual, 243
 martingale, 502
 outlier, 219, 227, 231
 partial residual, 243
 Pearson residual, 243
 residual standard error, 32
 residual sum of squares, 241
 residual variance, 29, 32, 33
 standard error, 23, 26
 standardized residual, 36
- risk factors, 65
- risk-ratio, 69
- sampling, 140
 frequency-severity, 141
 over-, 162
 two-part, 148
- sensitivity, 75
- shrinkage estimator, 198
- simultaneously autoregressive model, *see* spatial autoregression
- spatial autoregression
 conditionally autoregressive model, 265–267, 274
 intrinsically autoregressive model, 266–267
 proximity matrix, 266, 268, 274
 simultaneously autoregressive model, 267–268
- spatial statistic
 Geary's C , 264
 Moran's I , 263
- specificity, 75
- standard error of regression estimator, 27, 32
- stochastic process, 516
- survival data
 left-truncated, 482
 right-censored, 482
- survival function
 Kaplan-Meier estimator, 486
 Nelson-Aalen estimator, 490, 523
 nonparametric estimator, 486
 product-limit estimator, 486
- survival model
 cumulative hazard function, 481
 hazard function, 481
- test
 F -test, 243
 Hosmer-Lemeshow, 77
 likelihood ratio test (LRT), 76, 95, 200, 411, 531, 536
 Mantel-Haenzel, 495

- score, 95
- Wald, 95, 200
- Wilcoxon, 495
- threshold, 74
- time series inference
 - autocorrelation, 431, 437
 - autocovariance, 431
 - back casting, 435
 - Kalman filter, 445
 - prediction, 428, 442
- time series model
 - generalized autoregressive conditional heteroskedasticity (GARCH), 447
 - autoregressive of order 1 (AR(1)), 434
 - autoregressive, integrated, moving average (ARIMA), 440
 - autoregressive, moving average (ARMA), 434
 - autoregressive, moving average of order (p, q) , ARMA(p, q), 435
 - Box-Jenkins, 440
 - geometric random walk, 433
 - Lee-Carter, 447
 - moving average model of order q (MA(q)), 434
 - random walk, 432
 - seasonal ARIMA, 443
 - state space, 445
 - stochastic volatility, 446
 - structural, 443
 - white noise, 432
- time series model properties
 - invertibility, 437
 - stationarity, 429, 431, 434, 437
- transformation, 238
 - Box-Cox, 239, 371
 - inverse hyperbolic sine, 239
 - log-log, 491
 - logarithmic, 238
 - modified modulus, 240
 - modulus, 239
 - nonlinear, 239
 - signed power, 239
 - time series differencing, 430, 433, 440
 - time series lag operator, 435, 436, 440
 - variance stabilizing, 239
- transition intensity function, 519, 520, 522
 - cumulative intensity function, 523
- transition probability function, 178, 519, 520
- two-part distribution, 148
- underwriting, 3
- value-at-risk, 237
- variables
 - binary, 17, 66, 67
 - categorical, 17, 65, 66, 281
 - components, 282
 - dummy, 17
 - dynamic, 475
 - factor, 282
 - indicator, 17
 - Likert scale, 283
 - ordinal categorical, 79
 - scale, 281, 283
 - static, 475
 - unpredictable, 475