

Author Index

- Aalen, O. O., 140, 293, 304, 307
 Akaike, H., 98, 201
 Andersen, P. K., 59, 72, 293, 308, 319, 320, 322, 324
 Arjas, E., 312
 Bailey, W. G., 306
 Balevich, I., 173, 203, 209, 216
 Baxter, S., 34
 Beard, R. E., 52, 93
 Benjamin, B., 87, 92, 185, 186, 188, 300, 304, 305, 324
 Bielecki, T. R., 278
 Blake, D., 173, 203, 209, 214, 216, 243
 Booth, H., 224
 Borgan, Ø., 59, 72, 293, 308, 319, 320, 322, 324
 Bowers, N. L., 55
 Breslow, N. E., 305
 Brouhns, N., 173, 203, 212
 Cairns, A. J. G., 173, 203, 209, 214, 216, 243
 Camarda, C. G., 196, 205, 220, 221, 233
 Carstairs, V., 33, 35
 Carter, L., 209, 210, 225, 238, 242
 CMI, 61, 276–278, 293
 Collett, D., 100, 141
 Conte, S. D., 273
 Coughlan, G. D., 173, 203, 209, 216
 Cox, D. R., 71, 100, 101, 124
 Crowder, M., 299, 307
 Currie, I. D., 16, 27, 32, 36, 147, 174, 186, 203, 205, 207, 209, 211, 216, 220, 223, 231–233, 235, 238, 251, 252
 de Boor, C., 273
 Delwarde, A., 238
 Denuit, M., 173, 203, 212, 238
 Dickson, D. C. M., 55, 276, 302
 Dimitrova, S., 186
 Djeundje, V. A. B., 205, 207
 Dobson, A. J., 169, 170
 Dowd, K., 173, 203, 209, 214, 216, 243
 Durban, M., 186, 203, 209, 220, 233, 235
 Durbin, J., 108
 Efron, B., 242
 Eilbeck, J. C., 186
 Eilers, P. H. C., 186, 194, 196, 198, 201, 203, 207, 209, 220, 233, 235, 238
 Epstein, D., 173, 203, 209, 216
 Euler, L., 50
 Farewell, V. T., 305
 Feller, W., 279
 Firth, D., 212, 213
 Flannery, B. P., 273
 Fleming, T. R., 141, 308, 319, 320
 Flournoy, N. S., 305
 Forfar, D. O., 81, 88, 92, 109, 185
 Gaches, A., 34
 Gerber, H. U., 55, 276
 Gill, R., 59, 72, 293, 308, 319, 320, 322, 324
 Girosi, F., 211
 Gompertz, B., 75, 79, 93, 163, 185, 344, 346
 Green, P. J., 186
 Greenwood, M., 139
 Haberman, S., 173, 186
 Halley, E., 50
 Hannan, E. J., 99
 Hardy, M. R., 55, 147, 148, 207, 276, 302
 Harra, P., 312
 Harrington, D. P., 141, 308, 319, 320
 Hastie, T. J., 186, 198
 Hattendorff, K., 328

- Haycocks, H. W., 16, 47, 306
 Hickman, J. C., 55
 Hoem, J. M., 293
 Hurvich, C. M., 98
 Jones, D. A., 55
 Jones, G. L., 33
 Kahan, W., 344
 Kaishev, V. K., 186
 Kalbfleisch, J. D., 305, 319
 Kannisto, V., 93
 Kaplan, E. L., 134
 Karr, A. F., 318
 Kaufhold, K., 341
 Keiding, N., 59, 72, 293, 308, 319, 320, 322, 324
 Kendall, M. G., 108
 King, G., 211
 Kirkby, J. G., 32, 186, 220, 233
 Kleinow, T., 154, 242
 Lawless, J. F., 207
 Lee, R. D., 209, 210, 225, 238, 242
 Li, J. S. H., 207
 Macdonald, A. S., 298, 320
 Maclaurin, C., 50
 Madrigal, A., 34
 Makeham, W. M., 93, 185
 Marx, B. D., 186, 194, 196, 198, 201
 Matthews, F., 34
 McCullagh, P., 96, 97, 101, 177, 200, 207
 McCutcheon, J. J., 81, 88, 92, 109, 185, 186
 McLoone, P., 33, 35
 Meier, P., 134
 Miller, H. D., 71, 100, 101
 Morris, R., 33, 35
 Neill, A., 300
 Nelder, J. A., 96, 97, 101, 177, 178, 200, 207
 Nelson, W., 140
 Nesbitt, C. J., 55
 Ong, A., 173, 203, 209, 216
 Patel, D., 34
 Perks, W., 16, 47, 93, 185
 Perperoglou, A., 207
 Peterson, A. V., Jr., 305
 Philips, L., 28
 Pollard, J. H., 87, 92, 185, 186, 188, 300, 304, 305, 324
 Prentice, R. L., 305, 319
 Press, W. H., 273
 Quinn, B. G., 99
 Ramlau-Hansen, H., 326
 Redington, F. M., 306
 Renshaw, A. E., 173
 Richards, S. J., 8, 16, 27, 32–34, 36, 42, 81, 93, 110, 111, 113, 138, 147, 154, 186, 211, 220, 224, 231–233, 242, 251, 252, 341, 342, 344, 345
 Ritchie, G. P., 147, 231, 251, 252
 Rosenbusch, S., 341
 Rutkowski, M., 278
 Schwarz, G. E., 99, 203
 Shumway, R. H., 227
 Silverman, B. W., 186
 Spencer, J., 186
 Stoffer, D. S., 227
 Stuart, A., 108
 Sverdrup, E., 293
 Tan, K. S., 207
 Teukolsky, S. A., 273
 Thatcher, A. R., 93
 Thurston, S. W., 207
 Tibshirani, R. J., 186, 198, 242
 Tickle, L., 224
 Tsai, C. L., 98
 Tsiatis, A. A., 299
 Turner, H., 212, 213
 Vaupel, J. W., 93
 Vermunt, J. K., 173, 203, 212
 Vetterling, W. T., 273
 Wand, M. P., 207
 Waters, H. R., 55, 276, 293, 302
 Watson, G. S., 108
 Wedderburn, R. W. M., 178, 207
 Whittaker, E. T., 97, 186, 187
 Wiencke, J. K., 207
 Wilkie, A. D., 81, 88, 92, 109, 185
 Willets, R. C., 32, 113, 341
 Williams, D., 308, 310
 Wood, S. N., 186

Index

- B*-spline
 - basis, 189, 353
 - degree, 189
 - knots, 189
 - regression matrix, 191
- P*-spline model, 354
- P*-splines, 193
- χ^2 test, *see* goodness-of-fit tests
- 4GL, *see* fourth-generation language
- A/E comparison, 133
- Aalen's multiplicative model, 285
- Acorn, *see* geodemographic classification
- activities of daily living, *see* insurance
- actuarial estimate, 174, 304
- actuarial judgement, 153
- administration system, 15, 20
 - migration, 38
- aggregation of risk capital, 157
- AIC, *see* information criterion
- annuity, 26, 50, 327
- ARIMA(p, d, q) model, *see* time series
- ARMA(p, q) model, *see* time series
- AR(p) model, *see* time series
- autocorrelation coefficient, 109
- autoregressive integrated moving average model, *see* time series
- autoregressive model, *see* time series
- autoregressive moving average model, *see* time series
- balance sheet, 145
- baseline hazard, *see* proportional hazards
- BASIC, 329
- basis risk, 153
- Bernoulli
 - distribution, 71, 87
 - random variable, 318
- bias, 29, 36
- bias test, *see* goodness-of-fit tests
- BIC, *see* information criterion
- binomial
 - deviance, 96
 - distribution, 71, 87, 96
 - model, xiii, 71, 87, 88, 181
 - regression, 93, 173
- bisection method, 343
 - stochastic version, 343
- Black Death, 151
- Boole's rule, 346
- bootstrapping, 152
- Brownian motion, 314
- C, 329
- Cairns–Blake–Dowd model, xiv, 209, 214, 222, 243, 354
- canonical parameter, 177
- Carstairs index, 33
- CBD, *see* Cairns–Blake–Dowd model
- censoring, 58, 281
 - censoring hazard, 77
 - interval censoring, 59
 - left-censoring, 59
 - non-informative censoring, 59, 69
 - random censoring, 59, 77
 - right-censoring, xiii, 57, 58, 61, 63, 65, 67, 76, 77, 87, 135, 136, 289–291, 317, 322
 - Type I censoring, 59
 - Type II censoring, 59
- census formula, 73, 306
- central exposed-to-risk, *see* exposed-to-risk
- central rate of mortality, 9, 54, 69, 72
- Chapman–Kolmogorov equations, 260
- choice of smoothing parameter, *see* smoothing

- Cholesky factorisation, 332
 CMI, *see* Continuous Mortality Investigation
 coherence, 148
 cohort effect, 113
 comma-separated values, 24, 81
 competing risks model, xi, xv, 59, 294
 census formula, 306
 crude hazard rate, 297
 dependent hazard rate, 297
 independent hazard rate, 297
 latent failure time, 296
 latent lifetime, 296
 multiple-decrement model, 59, 78, 294
 net hazard rate, 297
 unidentifiability problem, 299
 concentration risk, 155
 conditional tail expectation, 147
 confidence interval, 169
 consistency condition, *see* random future lifetime
 Continuous Mortality Investigation, 61, 73, 276
 correlation matrix, 157
 correlation of risks, 146
 counting process, xv, 72, 257, 280, 285, 293, 307, 314, 315
 Aalen–Johansen estimator, 324
 compensator, xv, 317
 conditional expectation, 309, 310
 counting process martingale, 320
 Doob decomposition, 317
 Doob–Meyer decomposition, 317
 filtration, xv
 increments, 284
 Kaplan–Meier estimator, 324
 kernel smoothing, 324
 kernel, bandwidth, 324
 kernel, Epanechnikov, 324
 kernel, uniform, 324
 likelihood, 326
 Markov model, 321
 martingale, xv, 308, 314, 317
 martingale central limit theorem, 319
 multiple-state model, 257
 multivariate counting process, 281, 317, 324
 Nelson–Aalen estimator, 324
 orthogonality, 319
 parametric model, 325
 predictable process, 311
 previsible process, 311, 327
 product integral, 289, 324
 Riemann–Stieltjes integral, 313
 right-censoring, 322
 semi-Markov model, 321
 Stieltjes integral, 313
 stochastic integral, xv, 312
 Tower law, 311, 314, 316
 covariate, 61, 113, 123, 125, 129, 325
 age, 115
 benefit amount, 116
 categorical variable, 112
 continuous variable, 112
 gender, 113, 115, 125
 interactions between, 125
 pension amount, 113, 123, 125, 126
 pension scheme type, 122
 region of residence, 122
 smoking status, 113, 115
 socio-economic status, 115
 vector, 113, 122
 Cox model, 124
 baseline hazard, 124
 covariates, 124
 partial likelihood, 124
 proportional hazards, 124
 credit rating, 278
 cross-sectional mortality study, 64
 crude hazard rate, 68, 69, 129
 CSV, *see* comma-separated values file, 81, 331
 CTE, *see* conditional tail expectation
 cumulative distribution function, 148, 330
 curve of deaths, 52
 data
 bias, 29, 36
 corruption, signs of, 41
 deduplication, 16, 26
 exploratory plots, 41
 extraction, 20
 format, 24
 heaping, 31
 preparation, 37
 relationship checks, 25
 validation, 13, 25
 date format, 24
 European, 25
 ISO 8601, 25
 US, 25
 deduplication, 26
 key, 28, 35
 delta method, 170, 176
 density function, 330
 deviance, 95, 199, 200, 353

- information criterion (DIC), 99
 - residual, 101
- DIC, *see* information criterion
- differentiation, 349
- diversification benefit, 146
- drift
 - model, 226
 - parameter, 226
 - random walk with drift, 226
 - model, 239, 354
- earliest activity date, 23
- Ebola, 151
- effective dimension, 198, 353
- ELT, *see* English Life Table
- encapsulated Postscript, 333
- endowment, *see* insurance
- English Life Table No.16, 49
- equating reserves, 341
- Euler scheme, *see* multiple-state models
- European Union, 146
- event history analysis, 46
- Excel, 24, 148
 - PERCENTILE() function, 148
- expert judgement, 157
- exponential family, 177
- exposed-to-risk
 - central exposed-to-risk, 9, 67
 - initial exposed-to-risk, 9, 87, 173
- extensible markup language, 24
 - document type definition, 24
- failure rate, 51
- Fisher's information function, 334
- Fleming–Harrington estimator, *see*
 - non-parametric estimate
- force of interest, 55, 275, 313
- force of mortality, xiii, 50, 51
- forecasting, 224, 354
 - Cairns–Blake–Dowd model, 243
 - Lee–Carter model, 236
 - mortality projection, xii
 - penalty, 232
 - two-dimensional P -spline model, 247
- fourth-generation language, 329
- full model, 57, 59, 78, 125
- GAO, *see* guaranteed annuity rate
- GAR, *see* guaranteed annuity rate
- generalised linear model, 10, 178, 179, 332
 - offset, 10, 180
- geodemographic classification, 33
 - Acorn, 34
 - Mosaic, 34
- GLM, *see* generalised linear model
- Gompertz
 - law, 75, 79, 123, 163, 352
 - model, 69, 79, 80, 90, 115, 118, 124, 125, 166, 171, 173, 175, 179, 181, 352
 - paper, 75, 163, 185
- goodness-of-fit, xii, xiii, 67, 125, 131, 306
- goodness-of-fit tests
 - χ^2 test, 95, 102
 - bias test, 102, 107
 - bootstrapping, 109
 - lag-1 autocorrelation test, 108
 - runs test, 108
 - signs test, 107
 - standardised-deviations test, 102, 105
- graduation, 19, 69, 70, 76, 129, 291, 306
- Greenwood's formula, 139
- grouped counts, 6, 13
- guaranteed annuity rate, 23
- haemorrhagic fever, 151
- hat-matrix, 168
- Hattendorff's theorem, 328
- hazard rate, xiii, 50, 51, 66, 68, 71, 75, 114, 122, 129, 258, 285, 290, 291
- Hessian matrix, 83, 86
- HMD, *see* Human Mortality Database
- HQIC, *see* information criterion
- Human Mortality Database, 163, 165
 - reading data, 165
- ICA, *see* Individual Capital Assessment
- identifiable, 210
- idiosyncratic risk, 155
- illness–death model, 258
- indicator
 - of being under observation, 89, 281, 289, 291
 - of censoring, 66
 - of death, 65, 67, 78, 284
- Individual Capital Assessment, 147
- influenza, 21, 150
- information criterion, xiii, 95, 97, 122
 - AIC, 81, 85, 98, 115, 125, 129, 131, 198, 201, 353
 - AIC, small-sample correction, 98
 - BIC, 99, 198, 203, 353
 - DIC, 99
 - HQIC, 99
 - Schwarz, 99
- information loss, 13
- initial exposed-to-risk, *see* exposed-to-risk

- initial rate of mortality, 9
 insurance
 activities of daily living, 256
 benefit acceleration, 255
 critical illness, 47, 255
 disability, 47, 255, 258, 276, 292, 321
 dread disease, 255
 endowment, 26, 50
 income protection, 255
 life, 45, 46, 274, 327
 long-term care, 47, 255
 integral, 312
 approximation, 345
 Itô integral, 308, 312, 314
 product integral, 289
 Riemann–Stieltjes integral, 313
 Stieltjes integral, 313, 314
 stochastic integral, 312, 320
 integrated hazard function, 53, 92, 96, 344
 interval censoring, *see* censoring
 ISO 8601, 25
 Kaplan–Meier estimator, *see* non-parametric estimate
 Kolmogorov forward equations, *see* multiple-state model
 Kronecker product, 215, 219, 331, 350
 kurtosis, 333
 lag-1 autocorrelation test, *see* goodness-of-fit tests
 latest usable end date, 23
 late-reported deaths, 41
 law of large numbers, 55
 leap year, 82
 least squares, 166, 167, 170, 171, 175
 Lee–Carter model, xiv, 209, 210, 222, 236, 239, 353, 354
 left-censoring, *see* censoring
 left-truncation, xiii, 16, 57, 60, 67, 69, 87, 135, 281, 289, 291, 317, 322
 introducing bias, 60
 level risk, 151
 Lexis diagram, 61
 life insurance mathematics, 55, 274
 life table, 7, 49, 54, 63, 86, 274
 radix, 49
 select life table, 60
 linear predictor, 178, 179, 181
 link function, 179–181
 logit, 175
 log-likelihood, 95
 longevity, 63
 MA(q) model, *see* time series
 machine arithmetic
 overflow, 345
 underflow, 344
 Makeham model, *see* parametric model
 Markov Chain Monte Carlo methods, 99
 Markov model, xv, 54, 262, 286, 291, 321
 martingale, *see* counting process matrix
 positive semi-definite, 158
 maximum likelihood theorem, 336
 MCMC, *see* Markov Chain Monte Carlo
 median, 146, 148, 333
 metaphone encoding, 28
 mis-estimation risk, xii, 147
 model choice, 94
 model risk, 153, 251
 mortality law, *see* parametric model
 mortality projection, *see* forecasting
 mortality ratio, 6, 45, 63, 67, 68, 73, 76, 80, 87, 91, 288, 291
 Mosaic, *see* geodemographic classification
 moving average model, *see* time series
 multiple-decrement model, *see* competing risks model
 multiple-state model, 256, 279, 280, 328
 absorbing state, 264
 Chapman–Kolmogorov equations, 260
 coffin state, 264
 counting process, 257
 Euler scheme, 273
 indicator process, 257
 Kolmogorov forward equations, xv, 264, 266, 270, 276, 292
 Markov model, 262
 occupancy probability, 259
 reduced form credit risk model, 278
 Runge–Kutta algorithm, 273
 semi-Markov model, 263, 276
 single-decrement model, 54, 260, 325
 state space, 256
 Thiele’s differential equation, 274
 transition intensity, 51, 54, 259
 Nelson–Aalen estimator, *see* non-parametric estimate
 non-informative censoring, *see* censoring
 non-parametric estimate, xiv, 63, 132
 Aalen–Johansen estimator, 324
 Fleming–Harrington estimator, 141
 Kaplan–Meier definition, 134

- Kaplan–Meier estimator, 43, 112, 134, 324, 332
- Nelson–Aalen estimator, 140, 293, 324
- product-limit estimator, 138
- normal distribution, 69, 331
- numerical integration, 333, 344
- observational plan, 60
- occurrence-exposure rate, 45, 288, 293
- offset, *see* generalised linear model
- order statistic, 149
- overdispersion, 203, 205, 353
- parallel processing, 155
- parameter error, 227
- parameter space, 334
- parametric model, 75, 92, 131, 290, 325
 - Beard, 92
 - Gompertz, 75, 92
 - Gompertz–Makeham family, 92, 94, 131
 - Heligman–Pollard family, 92
 - logit Gompertz–Makeham family, 92
 - Makeham, 92, 185
 - Makeham–Beard, 92
 - Makeham–Perks, 92
 - Perks, 92
- partial likelihood, *see* Cox model
- PDF, *see* portable document format, 333
- penalisation, 194
- penalised likelihood, 196
- penalty, 194
- pension scheme, 17, 26
- phased retirement, 26
- PNG, *see* portable network graphic
- Poisson
 - deviance, 96
 - distribution, 12, 76, 95, 100, 279, 290, 332
 - limits for grouped counts, 11
 - model, xiii, 9, 71, 72, 87, 88, 179, 286, 288, 290, 291
 - process, 71, 284, 290
 - quasi-Poisson model, 206
 - random variable, 291, 292
 - regression, 172
- polynomial model, 182
- portable document format, 333
- portable network graphic file, 333
- postcode, 30
 - code postal (France), 35
 - district, 35
 - Postleitzahl (Germany), 35
 - sector, 33
 - UK, 33
- zip code, 33
- Postscript, 333
- prediction error, 229
- prediction interval, 169
- principle of correspondence, 73
- probabilistic model, 45, 57, 60, 63–65, 67, 69, 71, 73, 76, 77, 281, 291
- product integral, *see* counting process
- product-limit estimator, *see* non-parametric estimate
- proportional hazards, 122, 126
 - baseline hazard, 123
 - covariate, 123, 124
 - Cox model, 124, 326
- protected rights, 26
- p-value, 10
- quantile, 148, 330, 342
- quantile-quantile plot, 104, 333
- quasi-likelihood, 205
- quasi-Poisson model, *see* Poisson
- R, 5, 6, 82, 84, 137, 165, 183, 329
 - \$ symbol, 166
 - : operator, 165
 - ; symbol, 166
 - < operator, 165
 - FullNegLogL() function, 82
 - Logit() function, 176
 - MASS library, 247
 - Mort1DSmooth() function, 196, 198, 201, 205, 233–235, 332, 353, 354
 - Mort2DSmooth() function, 220, 248, 332, 354
 - MortalitySmooth package, 196, 198, 220, 233
 - Mult() function, 212
 - NegLogL() function, 80
 - Read.HMD() function, 165, 352
 - Surv() function, 332
 - WhittakerSmooth() function, 189, 352
 - %*% operator, 237, 332
 - & operator, 166, 331
 - a:b operator, 331
 - abs() function, 331
 - apply() function, 240, 332
 - arima() function, 229
 - arima.sim() function, 242
 - astsa package, 227, 229, 237, 354
 - axis() function, 333
 - bdeg argument, 191
 - bootstrap() function, 110

- R (cont.)
- bspline() function, 191, 353
 - c() function, 9, 83, 210, 212, 331
 - calculateDevianceResiduals() function, 96
 - cbind() function, 166, 332
 - chol() function, 158, 332
 - control option, 201
 - cumsum() function, 240, 331
 - deriv() function, 333
 - dev.off() function, 333
 - diag() function, 246, 332
 - diff() function, 226, 331
 - dim() function, 192, 246, 331
 - dnorm() function, 332
 - exp() function, 331
 - factor() function, 10, 212, 332
 - family option, 180
 - file option, 81
 - fit() function, 137, 332
 - for() loop, 199, 240, 331
 - function() function, 176, 199, 331
 - glm() function, 9, 10, 180, 182, 183, 192, 207, 332, 352, 354
 - gnm() function, 212, 332, 353, 354
 - gnm package, 212
 - gradient option, 84
 - gradtol option, 83
 - hdquantile() function, 333
 - header option, 81
 - help() function, 330, 331
 - hessian option, 83
 - install.packages() function, 329, 331
 - integrate() function, 53, 333, 344
 - kroncker() function, 215, 331
 - kurtosis() function, 333
 - legend() function, 184, 221, 333
 - length() function, 331
 - library() function, 191, 329, 331, 353
 - lines() function, 184, 333
 - lm() function, 167, 171, 175, 176, 332
 - load() function, 331
 - log() function, 331
 - ls() function, 331
 - lty option, 184
 - lwd option, 184
 - matlines() function, 333
 - matplot() function, 221, 240, 333
 - matpoints() function, 221, 333
 - matrix() function, 332
 - mean() function, 226, 333
 - median() function, 333
 - method option, 235
 - mvrnorm() function, 247
 - names() function, 166, 167, 331
 - ndx argument, 191
 - nlnm() function, 76, 80, 82, 124, 333
 - offset() function, 180
 - optim() function, 333
 - optimise() function, 333
 - overdispersion option, 205
 - par() function, 184, 333
 - pch option, 184
 - pdf() function, 333
 - plot() function, 184, 333
 - png() function, 333
 - points() function, 184, 333
 - porc option, 235
 - postscript() function, 333
 - predict() function, 169, 180, 207, 235, 248, 332
 - qnorm() function, 237
 - qqnorm() function, 104, 333
 - quantile() function, 148, 240, 333
 - read.csv() function, 80, 81, 331
 - rect() function, 333
 - relevel() function, 332
 - rep() function, 212, 331
 - rnorm() function, 240, 331
 - rpois() function, 332
 - sarima() function, 229, 332
 - sarima.for() function, 229, 332, 354
 - save() function, 331
 - se.fit option, 207
 - seq() function, 331
 - setEPS() function, 333
 - skewness() function, 333
 - solve() function, 81, 84, 332
 - source() function, 165, 352
 - source.csv() function, 331
 - splitExperienceByAge() function, 67
 - sqrt() function, 331
 - summary() function, 9, 10, 167, 331, 332
 - survival package, 137
 - survreg() function, 332
 - t() function, 216, 331, 332
 - text() function, 333
 - fontsize option, 83
 - var() function, 226, 331
 - vcov() function, 332
 - weights option, 171, 182
 - write.csv() function, 331

- w option, 234
- option, 83
- packages, 329
- programs, 351
- random censoring, *see* censoring
- random future lifetime, 46, 47, 50, 57, 66, 258, 291
 - consistency condition, 48, 51, 57
 - density function, 52
 - distribution function, 46, 47, 50
 - survival function, 47
- rate interval, 306
- reduced form credit risk model, 278
- regression model, 67, 93, 123
- regulation of insurance companies, xi, 145
- reinsurance treaty, 147
- reliability analysis, 46
- residuals, 100
 - deviance, 104, 115, 118, 125, 128, 129
 - Pearson, 101, 104
- reevaluation of pension amount, 18, 39
- right-censoring, *see* censoring
- risk
 - basis risk, 231
 - idiosyncratic risk, 231
 - mis-estimation risk, 231
 - model risk, 231
 - parameter risk, 231
 - stochastic risk, 231
 - volatility, 231
 - model, 251
- roughness, 194
- Runge–Kutta algorithm, *see* multiple-state model
- runs test, *see* goodness-of-fit tests
- saturated model, 95
- score function, 177, 334
- Scotland, 32
- seasonal mortality, 63
- secular mortality study, 64
- semi-Markov model, 263, 277, 292, 321
- significance
 - financial, xi, 109, 126
 - statistical, xi, 102
- Simpson's 3/8 rule, 346
- Simpson's rule, 346
- simulation, 238, 354
- skewness, 333
- smoothing
 - choice of smoothing parameter, 201
 - smoothing parameter, 188, 196
 - Whittaker, xiv, 186, 187, 353
- smoothing parameter, *see* smoothing
- SMR, *see* standardised mortality rate
- Solvency II, xi, 146–148, 153
- SQL, 20
- SST, *see* Swiss Solvency Test, 146
- standard error, 10
- standardised deviations test, *see* goodness-of-fit tests
- standardised mortality rate, 32
- stochastic error, 229
- stratification, xiv, 13, 87, 115, 120, 129, 131, 142, 263
- Student's *t* distribution, 331
- subadditivity, 148
- survival analysis, 15, 16, 46
- survival time, 8
- Swiss Solvency Test, 146, 147
- Thiele's differential equation, 274–276, 293
 - sum-at-risk, 275
- time lived, 6, 8
- time series, 225
 - ARIMA(p, d, q) model, 229, 332
 - ARMA(p, q) model, 229
 - AR(p) model, 228
 - autoregressive integrated moving average model, 229
 - autoregressive model, 228
 - autoregressive moving average model, 229
 - MA(q) model, 228
 - moving average model, 228
- Tower law, *see* counting process
- transition intensity, *see* multiple-state model
- trapezoidal rule, 345
- two-dimensional *P*-spline model, 209, 216, 222, 247
- Type I censoring, *see* censoring
- Type II censoring, *see* censoring
- uncertainty, xii
- underwriting, 56, 61
- United Kingdom, 32
- valuation margin, 145
- value-at-risk (VaR), 147
- variance-covariance matrix, 347
- waiting time, 284
- well-specified models, 12, 19
- Whittaker smoothing, *see* smoothing
- XML, *see* extensible markup language