### References

Pages on which each reference is cited are given in square brackets.

- Abraham, B. and J. Ledolter (1983) *Statistical methods for forecasting*, John Wiley & Sons, New York, USA. [292]
- Abramowitz, M. and I. A. Stegun (1964) *Handbook of mathematical functions with formulas, graphs, and mathematical tables*, vol. 55 of *NBS Applied Mathematics Series*, National Bureau of Standards, Washington, DC, tenth corrected printing ed. [332]
- Agrawal, N. and S. A. Smith (1996) Estimating negative binomial demand for retail inventory management with unobservable lost sales, *Naval Research Logistics*, **43**(6), 839–861. [315]
- Akaike, H. (1973) Information theory and an extension of the maximum likelihood principle, in B. N. Petrov and F. Csaki (eds.) *Second International Symposium on Information Theory*, pp. 267–281, Akdemiai Kiado, Budapest. [15]
- Akaike, H. (1974) A new look at the statistical model identification, *IEEE Transactions on Automatic Control*, **19**, 716–723. [15, 114, 220]
- Akaike, H. (1977) On entropy maximization principle, in P. R. Krishnaiah (ed.) *Applications of Statistics*, pp. 27–41, North Holland. [115]
- Akram, M., R. J. Hyndman and J. K. Ord (2007) Non-linear exponential smoothing and positive data, Working paper 14/07, Department of Econometrics & Business Statistics, Monash University. [265]
- Allen, P. G. and B. J. Morzuch (2006) Twenty-five years of progress, problems, and conflicting evidence in econometric forecasting. What about the next 25 years?, *International Journal of Forecasting*, **22**, 475–492. [304]
- Andersen, T. G., T. Bollerslev and N. Meddahi (2004) Analytical evaluation of volatility forecasts, *International Economic Review*, **45**(4), 1079–1110. [334]
- Anderson, B. D. O. and J. B. Moore (1979) *Optimal filtering*, Prentice-Hall, Englewood Cliffs. [14, 15, 222, 227, 298]
- Anderson, H. M., C. N. Low and R. D. Snyder (2006) Single source of error state-space approach to the Beveridge-Nelson decomposition, *Economics Letters*, **91**, 104–109. [337, 338]

- Anderson, T. W. (1958) *An introduction to multivariate statistical analysis*, John Wiley & Sons, New York, USA. [207]
- Anderson, T. W. (1971) *The statistical analysis of time series*, John Wiley and Sons, New York, USA. [184]
- Anderson, T. W. and D. A. Darling (1952) Asymptotic theory of certain "goodness of fit" criteria based on stochastic processes, *The Annals of Mathematical Statistics*, **23**(2), 193–212. [154]
- Ansley, C. F. and R. Kohn (1985) A structured state space approach to computing the likelihood of an ARIMA process and its derivatives, *Journal of Statistical Computation & Simulation*, **21**, 135–169. [208, 222]
- Aoki, M. (1987) State space modeling of time series, Springer-Verlag, Berlin. [14, 220]
- Aoki, M. and A. Havenner (1991) State space modelling of multiple time series, *Econometric Reviews*, **10**, 1–59. [15]
- Archibald, B. C. (1984) Seasonal exponential smoothing models, Working paper 30/1984, School of Business Administration, Dalhousie University, Halifax, Canada. [169]
- Archibald, B. C. (1990) Parameter space of the Holt-Winters' model, *International Journal of Forecasting*, **6**, 199–209. [24, 169]
- Archibald, B. C. (1991) Invertible region of damped trend, seasonal, exponential smoothing model, Working paper 10/1991, School of Business Administration, Dalhousie University, Halifax, NS. Canada. [165, 169]
- Archibald, B. C. and A. B. Koehler (2003) Normalization of seasonal factors in Winters' methods, *International Journal of Forecasting*, **19**, 143–148. [136]
- Assimakopoulos, V. and K. Nikolopoulos (2000) The theta model: a decomposition approach to forecasting, *International Journal of Forecasting*, **16**, 521–530. [23, 56]
- Athanasopoulos, G. and F. Vahid (2008a) A complete VARMA modelling methodology based on scalar components, *Journal of Time Series Analysis*, to appear. [303]
- Athanasopoulos, G. and F. Vahid (2008b) VARMA versus VAR for macroeconomic forecasting, to appear. [303]
- Bachelier, L. (1900) Théorie de la spéculation, Annales Scientifiques de l'École Normale Supérieure, 3(17), 21–86. [327]
- Bell, W. R. (1984) Signal extraction for nonstationary time series, *The Annals of Statistics*, **12**(2), 646–664. [232]
- Beveridge, S. and C. R. Nelson (1981) A new approach to decomposition of economic time series into permanent and transitory components with particular attention to measurement of the business cycle, *Journal of Monetary Economics*, 7, 151–174. [335, 337, 338, 344]
- Billah, B., R. J. Hyndman and A. B. Koehler (2003) Empirical information criteria for time series forecasting model selection, Working paper 02/03, Department of Econometrics & Business Statistics, Monash University. [114, 115, 126]

- Billah, B., R. J. Hyndman and A. B. Koehler (2005) Empirical information criteria for time series forecasting model selection, *Journal of Statistical Computation & Simulation*, **75**(10), 831–840. [115, 126]
- Black, F. and M. Scholes (1973) The pricing of options and corporate liabilities, *Journal of Political Economy*, **81**(3), 637–654. [327]
- Bollerslev, T. (1986) Generalized autoregressive conditional heteroscedasticity, *Journal of Econometrics*, **31**, 307–327. [329]
- Bowerman, B. L., R. T. O'Connell and A. B. Koehler (2005) *Forecasting, time series and regression: an applied approach,* Thomson Brooks/Cole, Belmont CA. [24]
- Bowman, K. O. and L. R. Shenton (1975) Omnibus test contours for departures from normality based on  $\sqrt{b_1}$  and  $b_2$ , Biometrika, **62**(2), 243–250. [154]
- Box, G. E. P. and D. R. Cox (1964) An analysis of transformations, *Journal of the Royal Statistical Society, Series B*, **26**(2), 211–252. [73]
- Box, G. E. P. and G. M. Jenkins (1970) *Time series analysis: forecasting and control*, Holden-Day, San Francisco. [171]
- Box, G. E. P., G. M. Jenkins and G. C. Reinsel (1994) *Time series analysis: fore-casting and control*, Prentice-Hall, Englewood Cliffs, New Jersey, 3rd ed. [14, 44, 77, 149, 175, 176, 223, 239]
- Brockwell, P. J. and R. A. Davis (1991) *Time series: theory and methods*, Springer-Verlag, New York, USA, 2nd ed. [45]
- Brown, R. G. (1959) *Statistical forecasting for inventory control*, McGraw-Hill, New York, USA. [13, 21, 22, 49, 240, 287, 294, 313, 317]
- Brown, R. G. (1963) *Smoothing, forecasting and prediction of discrete time series,* Prentice Hall, Englewood Cliffs, New Jersey. [13]
- Burridge, P. and K. F. Wallis (1988) Prediction theory for autoregressive-moving average processes, *Econometric Reviews*, 7(1), 65–95. [232]
- Caines, P. and D. Mayne (1970) On the discrete time matrix Riccati equation of optimal control, *International Journal of Control*, **12**, 785–794. [223]
- Caines, P. and D. Mayne (1971) On the discrete time matrix Riccati equation of optimal control: a correction, *International Journal of Control*, **14**, 205–207. [223]
- Campbell, J. and N. G. Mankiw (1987) Permanent and transitory components in macroeconomic fluctuations, *The American Economic Review*, **77**, 111–117.
- Canova, F. (1998) Detrending and business cycle facts, *Journal of Monetary Economics*, **41**, 475–512. [335]
- Chan, K. S. and J. Ledolter (1995) Monte Carlo EM estimation for time series models involving counts, *Journal of the American Statistical Association*, **90**(429), 242–252. [288]
- Charnes, A. and W. W. Cooper (1962) Programming with linear fractional functionals, *Naval Research Logistics Quarterly*, **9**, 181–186. [235]
- Chatfield, C. (1993) Calculating interval forecasts, *Journal of Business & Economic Statistics*, **11**, 121–135. [83]

- Chatfield, C. and M. Yar (1991) Prediction intervals for multiplicative Holt-Winters, *International Journal of Forecasting*, **7**, 31–37. [92]
- Chen, C. C. and W. J. Tsay (2006) The Beveridge-Nelson decomposition of Markov-switching processes, *Economics Letters*, **91**, 83–89. [344]
- Clarida, R. H. and M. P. Taylor (2003) Nonlinear permanent-temporary decompositions in macroeconometrics and finance, *Economic Journal*, **113**, C125–C139. [344]
- Cottet, R. and M. Smith (2003) Bayesian modeling and forecasting of intraday electricity load, *Journal of the American Statistical Association*, **98**(464), 839–849. [248]
- Croston, J. D. (1972) Forecasting and stock control for intermittent demands, *Operational Research Quarterly*, **23**(3), 289–304. [288, 291, 292, 294]
- de Jong, P. (1991a) The diffuse Kalman filter, *The Annals of Statistics*, **19**, 1073–1083. [208, 222]
- de Jong, P. (1991b) Stable algorithms for the state space model, *Journal of Time Series Analysis*, **12**, 143–157. [222]
- de Silva, A., R. J. Hyndman and R. D. Snyder (2007) The vector innovation structural time series framework: a simple approach to multivariate forecasting, Working paper 3/07, Department of Econometrics & Business Statistics, Monash University. [297, 302, 306, 308, 309]
- Doornik, J. A. and H. Hansen (1994) An omnibus test for univariate and multivariate normality, Working paper W4&91, Nuffield College, Oxford University. [154]
- Duncan, D. B. and S. D. Horn (1972) Linear dynamic recursive estimation from the viewpoint of regression analysis, *Journal of the American Statistical Association*, **67**, 815–821. [15]
- Durbin, J. and S. J. Koopman (2001) *Time series analysis by state space methods*, Oxford University Press, Oxford, UK. [15]
- Engle, R. F. (1982) Autoregressive conditional heteroscedasticity with estimates of the variance of United Kingdom inflation, *Econometrica*, **50**, 987–1007. [329]
- Engle, R. F. and C. W. J. Granger (1987) Cointegration and error-correction: Representation, estimation and testing, *Econometrica*, **55**, 251–276. [304]
- Fildes, R. (1992) The evaluation of extrapolative forecasting methods, *International Journal of Forecasting*, **8**, 81–98. [56]
- Friedman, M. (1957) *The theory of the consumption function*, Princeton University Press, Princeton, New Jersey. [336]
- Gallant, A. R. (1987) *Nonlinear statistical methods*, John Wiley & Sons, New York, USA. [76]
- Gardner, Jr, E. S. (1985) Exponential smoothing: the state of the art, *Journal of Forecasting*, **4**, 1–28. [20]
- Gardner, Jr, E. S. (2006) Exponential smoothing: the state of the art part II, *International Journal of Forecasting*, **22**(4), 637–666. [13]
- Gardner, Jr, E. S. and E. McKenzie (1985) Forecasting trends in time series, *Management Science*, **31**(10), 1237–1246. [23, 300]

- Gentleman, W. M. (1973) Least squares computations by Givens transformations without square roots, *IMA Journal of Applied Mathematics*, **12**(3), 329–336. [215]
- Geweke, J. F. and R. A. Meese (1981) Estimating regression models of finite but unknown order, *International Economic Review*, **22**, 55–70. [115]
- Gijbels, I., A. Pope and M. P. Wand (1999) Understanding exponential smoothing via kernel regression, *Journal of the Royal Statistical Society, Series B*, **61**(1), 39–50. [232]
- Gilchrist, W. G. (1967) Methods of estimation involving discounting, *Journal* of the Royal Statistical Society, Series B, **29**(2), 355–369. [289]
- Golub, G. H. and C. F. Van Loan (1996) *Matrix computations*, Johns Hopkins University Press, 3rd ed. [194, 213, 215]
- Gould, P., A. B. Koehler, F. Vahid-Araghi, R. D. Snyder, J. K. Ord and R. J. Hyndman (2008) Forecasting time series with multiple seasonal patterns, *European Journal of Operational Research*, to appear. [237]
- Granger, C. W. J. and P. Newbold (1986) *Forecasting economic time series*, Academic Press, New York, USA, 2nd ed. [223, 305]
- Graves, S. C. (1999) A single-item inventory model for a nonstationary demand process, *Manufacturing & Service Operations Management*, **1**(1), 50–61. [98, 313, 322]
- Grunwald, G. K., K. Hamza and R. J. Hyndman (1997) Some properties and generalizations of non-negative Bayesian time series models, *Journal of the Royal Statistical Society, Series B*, **59**, 615–626. [290]
- Hamilton, J. D. (1989) A new approach to the economic analysis of nonstationary time series and the business cycle, *Econometrica*, **57**(2), 357–384. [337]
- Hamilton, J. D. (1994) *Time series analysis*, Princeton University Press, Princeton, NJ. [76, 78]
- Hannan, E. J. (1980) The estimation of the order of an ARMA process, *The Annals of Statistics*, **8**, 1071–1081. [115]
- Hannan, E. J. and M. Deistler (1988) *The statistical theory of linear systems*, John Wiley & Sons, New York, USA. [14, 15, 158, 160, 227]
- Hannan, E. J. and B. Quinn (1979) The determination of the order of an autoregression, *Journal of the Royal Statistical Society, Series B*, **41**(2), 190–195. [114, 115]
- Harrison, P. J. (1967) Exponential smoothing and short-term sales forecasting, *Management Science*, **13**(11), 821–842. [91, 98]
- Harrison, P. J. (1997) Convergence and the constant dynamic linear model, *Journal of Forecasting*, **16**(5), 287–292. [223]
- Harrison, P. J. and C. F. Stevens (1976) Bayesian forecasting, *Journal of the Royal Statistical Society, Series B*, **38**(3), 205–247. [15]
- Harvey, A. C. (1985) Trends and cycles in macroeconomic time series, *Journal of Business & Economic Statistics*, **3**, 216–237. [335]
- Harvey, A. C. (1986) Analysis and generalisation of a multivariate exponential smoothing model, *Management Science*, **32**(3), 374–380. [299]

- Harvey, A. C. (1989) Forecasting, structural time series models and the Kalman filter, Cambridge University Press, Cambridge. [15, 145, 152, 153, 155, 184, 205, 219, 220, 222, 239, 297, 299, 305]
- Harvey, A. C. and C. Fernandes (1989) Time series models for count or qualitative observations, *Journal of Business & Economic Statistics*, **7**(4), 407–422. [288, 289]
- Harvey, A. C. and S. J. Koopman (2000) Signal extraction and the formulation of unobserved components models, *Econometrics Journal*, **3**, 84–17. [231]
- Harvey, A. C., E. Ruiz and N. Shephard (1994) Multivariate stochastic variance models, *Review of Economic Studies*, **61**, 247–264. [334]
- Heinen, A. (2003) Modeling time series count data: An autoregressive conditional Poisson model, CORE Discussion Paper 2003/62, Center of Operations Research and Econometrics, Université catholique de Louvain. [288]
- Heligman, L. and J. H. Pollard (1980) The age pattern of mortality, *Journal of the Institute of Actuaries*, **107**, 49–80. [335]
- Hendry, D. F. (1995) *Dynamic econometrics*, Oxford University Press, Oxford, UK. [304]
- Hillmer, S. C. and G. C. Tiao (1982) An ARIMA-model-based approach to seasonal adjustment, *Journal of the American Statistical Association*, 77, 63–70. [232]
- Holt, C. C. (1957) Forecasting trends and seasonals by exponentially weighted averages, O.N.R. Memorandum 52/1957, Carnegie Institute of Technology. [13, 22, 23, 52]
- Holt, C. C. (2004) Forecasting seasonals and trends by exponentially weighted moving averages, *International Journal of Forecasting*, **20**, 5–10. [13, 22]
- Hull, J. and A. White (1987) Hedging the risks from writing foreign currency options, *Journal of International Money and Finance*, **6**, 131–152. [328]
- Hurvich, C. M. and C. Tsai (1989) Regression and time series model selection in small samples, *Biometrika*, **76**, 297–307. [115]
- Hyndman, R. J. (2001) It's time to move from 'what' to 'why'—comments on the M3-competition, *International Journal of Forecasting*, **17**(4), 567–570. [83]
- Hyndman, R. J. (2004) The interaction between trend and seasonality, *International Journal of Forecasting*, **20**(4), 561–563. [19]
- Hyndman, R. J. (2007) forecast: Forecasting functions for time series, R package version 1.05. **URL:** http://www.robhyndman.info/Rlibrary/forecast/. [3]
- Hyndman, R. J. and M. Akram (2006) Some nonlinear exponential smoothing models are unstable, Working paper 3/06, Department of Econometrics & Business Statistics, Monash University. [265, 268, 272]
- Hyndman, R. J., M. Akram and B. C. Archibald (2008) The admissible parameter space for exponential smoothing models, *Annals of the Institute of Statistical Mathematics*, to appear. [157, 161, 164, 169]
- Hyndman, R. J. and B. Billah (2003) Unmasking the Theta method, *International Journal of Forecasting*, **19**(2), 287–290. [23, 56]

- Hyndman, R. J. and A. B. Koehler (2006) Another look at measures of forecast accuracy, *International Journal of Forecasting*, **22**, 679–688. [33, 34, 116]
- Hyndman, R. J., A. B. Koehler, J. K. Ord and R. D. Snyder (2005) Prediction intervals for exponential smoothing using two new classes of state space models, *Journal of Forecasting*, **24**, 17–37. [85]
- Hyndman, R. J., A. B. Koehler, R. D. Snyder and S. Grose (2002) A state space framework for automatic forecasting using exponential smoothing methods, *International Journal of Forecasting*, **18**(3), 439–454. [17, 20, 23, 31, 36, 81, 86, 122, 266, 271]
- Jarque, C. M. and A. K. Bera (1980) Efficient tests for normality, homoscedasticity and serial independence of regression residuals, *Economics Letters*, **6**(3), 255–259. [154]
- Jazwinski, A. H. (1970) *Stochastic processes and filtering theory*, Academic Press, New York, USA. [15]
- Johansen, S. (1988) Statistical analysis of cointegration vectors, *Journal of Economic Dynamics and Control*, **12**, 231–254. [304]
- Johnston, F. R. and J. E. Boylan (1996) Forecasting for items with intermittent demand, *Journal of the Operational Research Society*, **47**, 113–121. [291]
- Johnston, F. R. and P. J. Harrison (1986) The variance of lead-time demand, *Journal of the Operational Research Society*, **37**(3), 303–308. [91, 98, 313]
- Jung, R. C., M. Kukuk and R. Liesenfeld (2006) Time series of count data: modeling, estimation and diagnostics, *Computational Statistics & Data Analysis*, **51**, 2350–2364. [288]
- Kalman, R. E. (1960) A new approach to linear filtering and prediction problem, *Journal of Basic Engineering*, **82**(1), 35–45. [15, 187]
- Kalman, R. E. and R. S. Bucy (1961) New results in linear filtering and prediction theory, *Journal of Basic Engineering*, **83**(3), 95–108. [15]
- Kendall, M. G. (1953) The analysis of economic time-series part I: prices, *Journal of the Royal Statistical Society, Series A*, **116**(1), 11–34. [327]
- Kim, C. J. (1994) Dynamic linear models with Markov-switching, *Journal of Econometrics*, **60**, 1–22. [345]
- King, R. G., C. I. Plosser and S. Rebelo (1988) Production, growth and business cycles II: New directions, *Journal of Monetary Economics*, **21**, 309–341.
- Koehler, A. B., R. D. Snyder and J. K. Ord (2001) Forecasting models and prediction intervals for the multiplicative Holt-Winters' method, *International Journal of Forecasting*, **17**, 269–286. [92]
- Koning, A. J., P. H. Franses, M. Hibon and H. O. Stekler (2005) The M3 competition: Statistical tests of the results, *International Journal of Forecasting*, **21**(3), 397–409. [119]
- Lawton, R. (1998) How should additive Holt-Winters' estimates be corrected?, *International Journal of Forecasting*, **14**, 393–403. [161]
- Leeds, M. (2000) *Error structures for dynamic linear models: single source versus multiple source*, Ph.D. thesis, Department of Statistics, The Pennsylvania State University. [223, 229]

- Lilliefors, H. W. (1967) On the Kolmogorov-Smirnov test for normality with mean and variance unknown, *Journal of the American Statistical Association*, **62**(318), 399–402. [154]
- Ljung, G. M. and G. E. P. Box (1978) On a measure of lack of fit in time series models, *Biometrika*, **65**(2), 297–303. [153]
- Low, C. N., H. M. Anderson and R. D. Snyder (2006) Beveridge-Nelson decomposition with Markov switching, Melbourne Institute Working Paper 14/06, The University of Melbourne. [337, 344, 345]
- Lütkepohl, H. (2005) *New introduction to multiple time series analysis*, Springer-Verlag. [297, 309]
- Makridakis, S. (1993) Accuracy measures: theoretical and practical concerns, *International Journal of Forecasting*, **9**, 527–529. [34]
- Makridakis, S., A. Anderson, R. Carbone, R. Fildes, M. Hibon, R. Lewandowski, J. Newton, E. Parzen and R. Winkler (1982) The accuracy of extrapolation (time series) methods: Results of a forecasting competition, *Journal of Forecasting*, **1**, 111–153. [36]
- Makridakis, S. and M. Hibon (2000) The M3-competition: Results, conclusions and implications, *International Journal of Forecasting*, **16**, 451–476. [34, 36, 113, 116, 117, 254]
- Makridakis, S., S. C. Wheelwright and R. J. Hyndman (1998) *Forecasting: methods and applications*, John Wiley & Sons, New York, USA, 3rd ed. [19, 24, 80, 86]
- McClain, J. O. and L. J. Thomas (1973) Response-variance tradeoffs in adaptive forecasting, *Operations Research*, **21**, 554–568. [162]
- McKenzie, E. (1976) A comparison of some standard seasonal forecasting systems, *The Statistician*, **25**(1), 3–14. [231]
- McKenzie, E. (1986) Error analysis for Winters' additive seasonal forecasting system, *International Journal of Forecasting*, **2**, 373–382. [133]
- Merton, R. C. (1973) Theory of rational option pricing, Bell Journal of Economics and Management Science, 4(1), 141–183. [327]
- Miller, M. (1988) The Beveridge-Nelson decomposition of economic time series: another economical computational method, *Journal of Monetary Economics*, **21**, 141–142. [337]
- Morgan, F. (2005) Real analysis and applications: including Fourier series and the calculus of variations, American Mathematical Society, Providence, R.I. [105]
- Morley, J. C. (2002) A state-space approach to calculating the Beveridge-Nelson decomposition, *Economics Letters*, **75**, 123–127. [337]
- Morley, J. C., C. R. Nelson and E. Zivot (2003) Why are the Beveridge-Nelson and unobserved-components decompositions of GDP so different?, *The Review of Economics and Statistics*, **85**, 235–243. [340, 343]
- Muth, J. F. (1960) Optimal properties of exponentially weighted forecasts, *Journal of the American Statistical Association*, **55**(290), 299–306. [14]
- Nahmias, S. (1994) Demand estimation in lost sales inventory systems, *Naval Research Logistics*, **41**(6), 739–757. [315]

- Nelson, C. R. and C. I. Plosser (1982) Trends and random walks in macroeconomic time series, *Journal of Monetary Economics*, **10**, 132–162. [335]
- Nelson, D. B. (1991) Conditional heteroskedasticity in asset returns: A new approach, *Econometrica*, **59**(2), 347–370. [330]
- Newbold, P. (1990) Precise and efficient computation of the Beveridge-Nelson decomposition of economic time series, *Journal of Monetary Economics*, **26**, 453–457. [337, 344]
- Ord, J. K., A. B. Koehler and R. D. Snyder (1997) Estimation and prediction for a class of dynamic nonlinear statistical models, *Journal of the American Statistical Association*, **92**, 1621–1629. [15, 17, 24, 86, 88, 248]
- Ord, J. K. and P. Young (2004) Estimating the impact of recent interventions on transportation indicators, *Journal of Transportation and Statistics*, **7**, 69–85.
- Ouwehand, P., R. J. Hyndman, T. G. de Kok and K. H. van Donselaar (2007) A state space model for exponential smoothing with group seasonality, Working paper 07/07, Department of Econometrics & Business Statistics, Monash University. [299]
- Paige, C. C. and M. A. Saunders (1977) Least squares estimation of discrete linear dynamic systems using orthogonal transformations, *SIAM Journal on Numerical Analysis*, **14**(2), 180–193. [187]
- Park, J. W., M. G. Genton and S. K. Ghosh (2005) Censored time series analysis with autoregressive moving average models, Institute of Statistics Mimeo Series 2578, North Carolina State University. [315]
- Pearlman, J. G. (1980) An algorithm for the exact likelihood of a high-order autoregressive-moving average process, *Biometrika*, **67**(1), 232–233. [182]
- Pegels, C. C. (1969) Exponential forecasting: Some new variations, *Management Science*, **15**(5), 311–315. [20]
- Potter, S. (1995) A nonlinear approach to US GNP, *Journal of Applied Econometrics*, **10**(2), 109–125. [337]
- Press, W. H., S. A. Teukolsky, W. T. Vetterling and B. P. Flannery (2002) *Numerical recipes in C++: the art of scientific computing*, Cambridge University Press, Cambridge, 2nd ed. [324]
- Proietti, T. (2002) Forecasting with structural time series models, in Clements and Hendry (eds.) *A Companion to Economic Forecasting*, pp. 105–132, Prentice-Hall. [339]
- Proietti, T. and A. C. Harvey (2000) A Beveridge-Nelson smoother, *Economics Letters*, **67**, 139–146. [232]
- Ramanathan, R., R. F. Engle, C. W. J. Granger, F. Vahid-Araghi and C. Brace (1997) Short-run forecasts of electricity loads and peaks, *International Journal of Forecasting*, **13**, 161–174. [248]
- Roberts, S. A. (1982) A general class of Holt-Winters type forecasting models, *Management Science*, **28**(8), 808–820. [133, 169]
- Robinson, P. M. (1980) Estimation and forecasting for time series containing censored or missing observations, in O. D. Anderson (ed.) *Time Series*, pp. 167–182, North-Holland, Amsterdam. [315]

- Schott, J. R. (2005) *Matrix analysis for statistics*, John Wiley and Sons, Hoboken, NJ, 2nd ed. [94]
- Schwarz, G. (1978) Estimating the dimension of a model, *The Annals of Statistics*, **6**, 461–464. [114, 115]
- Schweppe, F. (1965) Evaluation of likelihood functions for Gaussian signals, *IEEE Transactions on Information Theory*, **11**, 61–70. [192, 221]
- Shenstone, L. and R. J. Hyndman (2005) Stochastic models underlying Croston's method for intermittent demand forecasting, *Journal of Forecasting*, **24**, 389–402. [292]
- Shibata, R. (1976) Selection of the order of an autoregressive model by Akaike's information criterion, *Biometrika*, **63**, 117–126. [115]
- Shiryaev, A. N. (1984) Probability, Springer-Verlag, New York, USA. [272]
- Silver, E. A., D. F. Pyke and R. Peterson (1998) *Inventory management and production planning and scheduling*, Wiley, New York, USA, 3rd ed. [313]
- Silverman, B. W. (1986) *Density estimation for statistics and data analysis*, Chapman and Hall, London. [87]
- Sims, C. A. (1980) Macroeconomics and reality, *Econometrica*, **48**(1), 1–48. [303] Snyder, R. D. (1980) The safety stock syndrome, *Journal of the Operational Research Society*, **31**, 833–837. [319]
- Snyder, R. D. (2002) Forecasting sales of slow and fast moving inventories, *European Journal of Operational Research*, **140**, 684–699. [292]
- Snyder, R. D. and C. S. Forbes (2003) Reconstructing the Kalman filter for stationary and non stationary time series, *Studies in Nonlinear Dynamics and Econometrics*, **7**(2), 1–18. [161, 208]
- Snyder, R. D., A. B. Koehler, R. J. Hyndman and J. K. Ord (2004) Exponential smoothing models: Means and variances for lead-time demand, *European Journal of Operational Research*, **158**(2), 444–455. [85, 98]
- Snyder, R. D., A. B. Koehler and J. K. Ord (1999) Lead time demand for simple exponential smoothing: an adjustment factor for the standard deviation, *Journal of the Operational Research Society*, **50**, 1079–1082. [98, 313]
- Snyder, R. D., G. M. Martin, P. Gould and P. D. Feigin (2007) An assessment of alternative state space models for count time series, Working paper 4/07, Department of Econometrics & Business Statistics, Monash University. [288]
- Snyder, R. D., J. K. Ord and A. B. Koehler (2001) Prediction intervals for ARIMA models, *Journal of Business & Economic Statistics*, **19**(2), 217–225. [88]
- Solow, R. M. (1956) A contribution to the theory of economic growth, *Quarterly Journal of Economics*, **70**, 65–94. [336]
- Stirling, W. D. (1981) Least squares subject to linear constraints, *Journal of Applied Statistics*, **30**, 204–212. [194, 215]
- Stock, J. H. and M. W. Watson (1988) Variable trends in economic time series, *Journal of Economic Perspectives*, **2**(3), 147–174. [336, 340]
- Stuart, A. and J. K. Ord (1994) *Kendall's advanced theory of statistics. Vol. 1: Distribution theory*, Hodder Arnold, London, 6th ed. [268, 273, 275, 277, 287]

- Sugiura, N. (1978) Further analysis of the data by Akaike's information criterion and the finite corrections, *Communications in Statistics*, **A7**, 13–26. [114, 115]
- Sweet, A. L. (1985) Computing the variance of the forecast error for the Holt-Winters seasonal models, *Journal of Forecasting*, **4**, 235–243. [161]
- Syntetos, A. A. and J. E. Boylan (2001) On the bias of intermittent demand estimates, *International Journal of Production Economics*, **71**, 457–466. [291, 292]
- Syntetos, A. A. and J. E. Boylan (2005) The accuracy of intermittent demand estimates, *International Journal of Forecasting*, **21**, 303–314. [291, 292]
- Taylor, J. W. (2003a) Exponential smoothing with a damped multiplicative trend, *International Journal of Forecasting*, **19**, 715–725. [20, 72]
- Taylor, J. W. (2003b) Short-term electricity demand forecasting using double seasonal exponential smoothing, *Journal of the Operational Research Society*, **54**, 799–805. [239, 240, 255]
- Teräsvirta, T. and H. M. Anderson (1992) Characterizing nonlinearities in business cycles using smooth transition autoregressive models, *Journal of Applied Econometrics*, **7**, S119–S136. [337]
- Tsay, R. S. (2005) *Analysis of financial time series*, John Wiley & Sons, New York, USA, 2nd ed. [149, 330, 334]
- Watson, M. W. (2003) Macroeconomic forecasting using many predictors, in *Advances in economics and econometrics, theory and applications*, vol. 3, pp. 87–115, Eighth World Congress of the Econometric Society. [309]
- West, M. and P. J. Harrison (1997) *Bayesian forecasting and dynamic models*, Springer-Verlag, New York, USA, 2nd ed. [15, 63, 220]
- Willemain, T. R., C. N. Smart, J. H. Shockor and P. A. DeSautels (1994) Fore-casting intermittent demand in manufacturing: a comparative evaluation of Croston's method, *International Journal of Forecasting*, **10**, 529–538. [292]
- Williams, D. (1991) *Probability with martingales*, Cambridge University Press, Cambridge. [272]
- Winters, P. R. (1960) Forecasting sales by exponentially weighted moving averages, *Management Science*, **6**, 324–342. [13, 23, 54, 239]
- Working, H. (1960) Note on the correlation of first differences of averages in a random chain, *Econometrica*, **28**, 916–918. [327, 334]
- Yar, M. and C. Chatfield (1990) Prediction intervals for the Holt-Winters forecasting procedure, *International Journal of Forecasting*, **6**, 127–137. [91, 98]
- Yurkiewicz, J. (2006) 2006 forecasting software survey, *OR/MS Today*, **33**(4), 40–49. [4]
- Zarnowitz, V. and C. Boschan (1977) Cyclical indicators, in *57th annual report*, pp. 34–38, National Bureau of Economic Research. [336]
- Zellner, A. (1962) An efficient method of estimating seemingly unrelated regressions and tests for aggregation bias, *Journal of the American Statistical Association*, **57**, 348–368. [299]

## **Author index**

Abraham, B., 292 Abramowitz, M., 332 Agrawal, N., 315 Akaike, H., 15, 114, 115, 220 Akram, M., 157, 161, 164, 169, 265, 268, Allen, P. G., 304 Andersen, T. G., 334 Anderson, A., 36 Anderson, B. D. O., 14, 15, 222, 227, 298 Anderson, H. M., 337, 338, 344, 345 Anderson, T. W., 154, 184, 207 Ansley, C. F., 208, 222 Aoki, M., 14, 15, 220 Archibald, B. C., 24, 136, 157, 161, 164, 165, 169 Assimakopoulos, V., 23, 56 Athanasopoulos, G., 303

Bachelier, L., 327
Bell, W. R., 232
Bera, A. K., 154
Beveridge, S., 335, 337, 338, 344
Billah, B., 23, 56, 114, 115, 126
Black, F., 327
Bollerslev, T., 329, 334
Boschan, C., 336
Bowerman, B. L., 24
Bowman, K. O., 154
Box, G. E. P., 14, 44, 73, 77, 149, 153, 171, 175, 176, 223, 239
Boylan, J. E., 291, 292
Brace, C., 248
Brockwell, P. J., 45

Brown, R. G., 13, 21, 22, 49, 240, 287, 294, 313, 317 Bucy, R. S., 15 Burridge, P., 232

Caines, P., 223
Campbell, J., 339, 340
Canova, F., 335
Carbone, R., 36
Chan, K. S., 288
Charnes, A., 235
Chatfield, C., 83, 91, 92, 98
Chen, C. C., 344
Clarida, R. H., 344
Cooper, W. W., 235
Cottet, R., 248
Cox, D. R., 73
Croston, J. D., 288, 291, 292, 294

Darling, D. A., 154
Davis, R. A., 45
de Jong, P., 208, 222
de Kok, T. G., 299
de Silva, A., 297, 302, 306, 308, 309
Deistler, M., 14, 15, 158, 160, 227
DeSautels, P. A., 292
Doornik, J. A., 154
Duncan, D. B., 15
Durbin, J., 15

Engle, R. F., 248, 304, 329

Feigin, P. D., 288 Fernandes, C., 288, 289 Fildes, R., 36, 56 Flannery, B. P., 324 Forbes, C. S., 161, 208 Franses, P. H., 119 Friedman, M., 336

Gallant, A. R., 76
Gardner, E. S., Jr, 13, 20, 23, 300
Gentleman, W. M., 215
Genton, M. G., 315
Geweke, J. F., 115
Ghosh, S. K., 315
Gijbels, I., 232
Gilchrist, W. G., 289
Golub, G. H., 194, 213, 215
Gould, P., 237, 288
Granger, C. W. J., 223, 248, 304, 305
Graves, S. C., 98, 313, 322
Grose, S., 17, 20, 23, 31, 36, 81, 86, 122, 266, 271
Grunwald, G. K., 290

Hamilton, J. D., 76, 78, 337 Hamza, K., 290 Hannan, E. J., 14, 15, 114, 115, 158, 160, 227 Hansen, H., 154 Harrison, P. J., 15, 63, 91, 98, 220, 223, 313 Harvey, A. C., 15, 145, 152, 153, 155, 184, 205, 219, 220, 222, 231, 232, 239, 288, 289, 297, 299, 305, 334, 335 Havenner, A., 15 Heinen, A., 288 Heligman, L., 335 Hendry, D. F., 304 Hibon, M., 34, 36, 113, 116, 117, 119, 254 Hillmer, S. C., 232 Holt, C. C., 13, 22, 23, 52 Horn, S. D., 15 Hull, J., 328 Hurvich, C. M., 115 Hyndman, R. J., 3, 17, 19, 20, 23, 24, 31, 33, 34, 36, 56, 80, 81, 83, 85, 86, 98, 114-116, 122, 126, 157, 161, 164, 169, 237, 265, 266, 268, 271, 272, 290, 292,

Jarque, C. M., 154

297, 299, 302, 306, 308, 309

Jazwinski, A. H., 15 Jenkins, G. M., 14, 44, 77, 149, 171, 175, 176, 223, 239 Johansen, S., 304 Johnston, F. R., 91, 98, 291, 313 Jung, R. C., 288

Kalman, R. E., 15, 187 Kendall, M. G., 327 Kim, C. J., 345 King, R. G., 346 Koehler, A. B., 15, 17, 20, 23, 24, 31, 33, 34, 36, 81, 85, 86, 88, 92, 98, 114–116, 122, 126, 136, 237, 248, 266, 271, 313 Kohn, R., 208, 222 Koning, A. J., 119 Koopman, S. J., 15, 231 Kukuk, M., 288

Lawton, R., 161 Ledolter, J., 288, 292 Leeds, M., 223, 229 Lewandowski, R., 36 Liesenfeld, R., 288 Lilliefors, H. W., 154 Ljung, G. M., 153 Low, C. N., 337, 338, 344, 345 Lütkepohl, H., 297, 309

Makridakis, S., 19, 24, 34, 36, 80, 86, 113, 116, 117, 254 Mankiw, N. G., 339, 340 Martin, G. M., 288 Mayne, D., 223 McClain, J. O., 162 McKenzie, E., 23, 133, 231, 300 Meddahi, N., 334 Meese, R. A., 115 Merton, R. C., 327 Miller, M., 337 Moore, J. B., 14, 15, 222, 227, 298 Morgan, F., 105 Morley, J. C., 337, 340, 343 Morzuch, B. J., 304 Muth, J. F., 14

Nahmias, S., 315 Nelson, C. R., 335, 337, 338, 340, 343, 344

#### 362 Author index

Nelson, D. B., 330 Newbold, P., 223, 305, 337, 344 Newton, J., 36 Nikolopoulos, K., 23, 56

O'Connell, R. T., 24 Ord, J. K., 15, 17, 24, 85, 86, 88, 92, 98, 156, 237, 248, 265, 268, 273, 276, 277, 287, 313 Ouwehand, P., 299

Paige, C. C., 187 Park, J. W., 315 Parzen, E., 36 Pearlman, J. G., 182 Pegels, C. C., 20 Peterson, R., 313 Plosser, C. I., 335, 346 Pollard, J. H., 335 Pope, A., 232 Potter, S., 337 Press, W. H., 324 Proietti, T., 232, 339 Pyke, D. F., 313

Quinn, B., 114, 115

Ruiz, E., 334

Ramanathan, R., 248 Rebelo, S., 346 Reinsel, G. C., 14, 44, 77, 149, 175, 176, 223, 239 Roberts, S. A., 133, 169 Robinson, P. M., 315

Saunders, M. A., 187 Scholes, M., 327 Schott, J. R., 94 Schwarz, G., 114, 115 Schweppe, F., 192, 221 Shenstone, L., 292 Shenton, L. R., 154 Shephard, N., 334 Shibata, R., 115 Shiryaev, A. N., 272 Shockor, J. H., 292 Silver, E. A., 313 Silverman, B. W., 87 Sims, C. A., 303 Smart, C. N., 292 Smith, M., 248 Smith, S. A., 315

Snyder, R. D., 15, 17, 20, 23, 24, 31, 36, 81, 85, 86, 88, 92, 98, 122, 161, 208, 237, 248, 266, 271, 288, 292, 297, 302, 306, 308, 309, 313, 319, 337, 338, 344, 345

Solow, R. M., 336 Stegun, I. A., 332 Stekler, H. O., 119 Stevens, C. F., 15 Stirling, W. D., 194, 215 Stock, J. H., 336, 340

Stuart, A., 268, 273, 276, 277, 287 Sugiura, N., 114, 115

Sweet, A. L., 161 Syntetos, A. A., 291, 292

Taylor, J. W., 20, 72, 239, 240, 255 Taylor, M. P., 344 Teräsvirta, T., 337 Teukolsky, S. A., 324 Thomas, L. J., 162 Tiao, G. C., 232 Tsai, C., 115

Tsay, R. S., 149, 330, 334 Tsay, W. J., 344

Vahid-Araghi, F., 237, 248 Vahid, F., 303 van Donselaar, K. H., 299 Van Loan, C. F., 194, 213, 215 Vetterling, W. T., 324

Wallis, K. F., 232 Wand, M. P., 232 Watson, M. W., 309, 336, 340

West, M., 15, 63, 220 Wheelwright, S. C., 19, 24, 80, 86

White, A., 328 Willemain, T. R., 292 Williams, D., 272 Winkler, R., 36

Winters, P. R., 13, 23, 54, 239 Working, H., 327, 334

Yar, M., 91, 92, 98 Young, P., 156 Yurkiewicz, J., 4

Zarnowitz, V., 336 Zellner, A., 299 Zivot, E., 340, 343

# **Data index**

annual US net electricity generation, 11, annual US new freight cars, 280-281 hourly utility demand, 248-255 hourly vehicle counts, 255-258 M3 competition data, 117–122 monthly Australian overseas visitors, 11,36 monthly Canadian gas production, 139 monthly copper prices, 346 monthly Dow Jones Index, 74, 330-332, monthly exchange rates, 306-309 monthly hospital patient count, 123-124 monthly product sales, 325 monthly sales car parts, 293-296 monthly US civilian unemployment, 156

monthly US consumer confidence, 156 monthly US domestic enplanements, 156 monthly US gasoline prices, 149–151, 333–334 monthly US government bond yields, 11, 36, 102

quarterly Australian GDP, 78–80, 340–344 quarterly French exports, 86, 96 quarterly UK GDP, 340–344 quarterly UK passenger vehicle production, 11, 36, 102 quarterly US GDP, 82 quarterly US GNP, 340–344

Watson macroeconomic database, 309 weekly FM sales, 147–149 weekly jewelry sales, 282–284

# Subject index

BIC, 35, 114, 115, 124

Black-Scholes model, 328-329

Brown's double exponential

smoothing, 22

Brownian motion, 328

Box-Ljung-Pierce statistic, 153, 154

accuracy of forecast, 33-34 business cycle, 18, 335-337, 342, 344, additive error models, 25, 27-29 aggregate demand, see lead-time see also cycle demand canonical model, 219, 220 AIC, 35, 114-116, 120, 122, 124, 125, 203, Cauchy distribution, 268 204, 302, 303 causal stationarity, 172, 173, AICc, 114, 115, 124 see also stationarity airline model, 176, 179 Akaike's Information Criterion, see AIC censored data, 314, 315 and AICc cointegrated models, 304 composite models, 58 ARCH/GARCH models, 329-333 conditional heteroscedasticity, 327-334 ARIMA models, 171-185, 204, 223, convergence of estimates, 76, 222, 223 227-232, 234, 239, 245, 261, 262, convergence to zero problem, 269, 276, 297, 337, 338, 340–345 281, 286, 290, 291 multiplicative seasonal model, 175 augmented sum of squared errors, see sum of squared errors autocovariance generating function, 230 automatic forecasting, 35-36 autoregressive conditional heteroscedastic models, see ARCH/GARCH models Bayesian Information Criterion, see BIC Bernoulli distribution, 292 Beveridge-Nelson decomposition, 232, 335-346

count data, 287-296 Croston's method, 291-294 cycle, 18, 237, 335, 336, 339 cyclical models, 184-185 damped level model, 55, 188, 195 damped trend, 19, 20, 23, 56, 59, 72, 74, 116, 119-122, 124, 125, 134, 137, 183, 189, 190, 195, 196, 300, 304, 306-308, 310 damping matrix, 300 demand data, 291, 313 differencing, 175, 176, 180, 204 discount matrix, 45, 56, 160, 162, 170 discounted sum of squared errors, 289 double exponential smoothing, 22 double seasonal method, 239-241, 246, 247, 252, 255-259

drift, 328, 335, 336, 338, 344,

see also local level model with drift, see also random walk with drift dummy variable, see indicator variable dynamic linear models, 15

efficient market hypothesis, 66, 327
EGARCH models, 330
empirical information criterion, see
LEIC
estimability, 15, 219
estimation, 32, 75–82, 138, 147, 191–193,
220–223, 247, 293, 300–302, 330,
see also heuristic estimation,
see also least squares estimation,
see also maximum likelihood estimation,
see also optimization
ETS notation, 25
ETS(A,A,A), 29, 36, 53–54, 84, 89, 90, 99,
102, 103, 106, 112, 118, 131, 158,
159, 161, 162, 164–170, 179, 226,

239, 240, 300 ETS(A,A,M), 29, 71, 84, 118, 266 ETS(A,A,N), 27, 29, 37, 50–53, 74, 84, 89, 90, 99, 103, 106, 118, 158, 162, 163,

ETS(A,A<sub>d</sub>,A), 29, 84, 89, 90, 99, 103–106, 112, 118, 120, 134, 135, 158, 159, 162, 164–170

ETS(A,A<sub>d</sub>,M), 29, 84, 118, 142, 266 ETS(A,A<sub>d</sub>,N), 29, 36, 56, 59, 84, 89, 90, 99, 102, 103, 106, 118–120, 122, 125, 158, 162, 163, 170

ETS(A,M,A), 29, 84, 118, 266 ETS(A,M,M), 29, 74, 84, 118, 266 ETS(A,M,N), 29, 67, 68, 84, 118, 266–269 ETS(A,M<sub>d</sub>,A), 29, 84, 118, 142, 266 ETS(A,M<sub>d</sub>,M), 29, 74, 84, 118, 266 ETS(A,M<sub>d</sub>,N), 29, 84, 118, 266 ETS(A,N,A), 29, 36, 57, 84, 89, 90, 99,

102, 103, 106, 118, 151, 158, 159, 162, 164–166, 170 ETS(A,N,M), 29, 84, 118, 266

ETS(A,N,N), 29, 37, 48–50, 59, 62, 82, 84, 89, 90, 99–101, 103, 106, 118, 119, 151, 156, 158, 162, 163, 170, 176, 273, 280–283

ETS(M,A,A), 30, 84, 89, 91, 118

94–96, 118, 119, 239
ETS(M,A,N), 27, 30, 66–67, 73, 74, 84, 89, 91, 118
ETS(M,A<sub>d</sub>,A), 30, 36, 84, 89, 91, 118, 134, 135
ETS(M,A<sub>d</sub>,M), 30, 84, 92, 93, 110, 118–120, 122, 137, 142
ETS(M,A<sub>d</sub>,N), 30, 36, 72, 74, 84, 89, 91, 118
ETS(M,M,A), 30, 84, 118, 266
ETS(M,M,M), 30, 74, 84, 118, 279
ETS(M,M,N), 30, 68, 84, 118, 286
ETS(M,M,A), 30, 84, 118, 266

ETS(M,A,M), 30, 36, 69, 84, 86, 92,

ETS(M,M,d,A), 30, 84, 118, 266 ETS(M,M<sub>d</sub>,M), 30, 74, 84, 118, 142, 280 ETS(M,M<sub>d</sub>,N), 30, 36, 84, 118, 286 ETS(M,N,A), 30, 84, 89, 91, 118 ETS(M,N,M), 30, 84, 92, 93, 118, 139, 286 ETS(M,N,N), 30, 37, 62, 65–66, 74, 84, 89, 91, 102, 118, 269–275, 279–286

exponentially weighted moving average, 21, 50, 289, 290, 292

fast Givens transformation, 194, 210, 213–215

fill rate, 322, 323

finite start-up assumption, 42, 55, 172, 187, 191, 192, 208

forecast, see point forecast

 $forecast\ accuracy,\ 33\text{--}34$ 

forecast errors, 21, 33,

see also percentage errors, see also scaled errors

forecast interval, *see* prediction interval forecast mean, 83, 89, 91–96, 98–101, 103, 104, 107–111, 131, 134–136, 138, 248, 302

forecast variance, 83, 90–111, 131, 134–136, 138, 142, 302, see also infinite variance problem forecastability, 44, 45, 56, 59, 160–169, 229, 230, 234, 235, 300 forecasting method, 12, 20 forecasting software, 3

gamma distribution, 275–277 GARCH, see ARCH/GARCH models Gaussian elimination, 211, 212 general exponential smoothing, 44, 77

### 366 Subject index

global trend, 51, 66 goodness-of-fit measures, 152, 153 Granger-Newbold theorem, 223, 224, 305 group seasonality, 299, 300 growth cycles, 336, 337

Hannan-Quinn information criterion, see HQIC
heteroscedasticity, 62, 73, 85, 91, 147, 155, 329–334
heuristic estimation, 31, 32, 79–81
history of exponential smoothing, 13–14
Hodrick-Prescott filter, 335
Holt's method, 13, 20, 22, 23, 27–28, 52, 177
Holt-Winters' method, 13, 20, 23–25, 70,

73, 91, 98, 161, 164, 231, 239–242, 247, 252, 256–259, 300 homogeneous coefficient models, 299 hourly data, 237, 238, 240–243, 248–258

identifiability, 219, 226 IGARCH models, 329 indicator variable, 145–148, 156, 241–243, 259, 291 infinite start-up assumption, 42, 46, 172,

HQIC, 114, 115, 124

191, 203, 208, 217 infinite variance problem, 267–269

infinite variance problem, 267–269 information criteria, 35, 113–116,

AIC, BIC, AICc, HQIC and LEIC information filter, 187, 193–201, 210, 220 initialization, 22, 31–32, 195–196, 252, 301, 302

innovation, 42, 43, 77 innovations state space models, 14–15, 28–31

linear, 14, 41–59, 89–91, 157–170 nonlinear, 14, 61–74, 265–286 random seed, 188 intermittent demand data, 291

interventions, 145–147, 156 inventory control, 88, 313–325 inventory control systems, 318–324 invertibility, 45, 174, 176, 177, 179, 180,

231

Kakutani's theorem, 271–272 Kalman filter, 63, 187, 205–208, 220–222 augmented, 222 Kalman gain, 207 kernel density estimation, 87 kernel smoothing, 232 Kullback-Leibler distance, 115

lag operator, 159, 171 lead-time, 314 stochastic, 101, 102 lead-time demand, 88 lead-time demand forecasts, 83, 88-89, 98-102 leading indicators, 147, 149-151 least squares estimation, 78, 79, 192 LEIC, 114, 115, 124, 126-127 likelihood, 32, 76, 77, 113, 114, 191–193, 203, 221, 222, 277-278, 289, 301 linear innovations state space models, see innovations state space models local level model, 47–50, 59, 62, 65–66, 146, 148, 151, 153, 185, 189, 195, 225, 228, 271, 276, 288, 290, 292, 300, 302, 304–307, 314, 316, 322, 330, 332, 333, see also

330, 332, 333, see also ETS(A,N,N) and ETS(M,N,N), see also simple exponential smoothing with drift, 23, 55, 56, 59, 72, 74, 82, 162, 330, 332, 339

local negative binomial model, 289, 290, 294, 296

local Poisson model, 288, 294, 296 local trend model, 47, 50–53, 56, 66–67, 72–74, 79, 80, 198, 227–230, 234, 235, 300, 302, 304–308, 310, see also

ETS(A,A,N) and ETS(M,A,N) lognormal distribution, 272–275, 277, 278, 328 lost sales, 314, 315, 317

M3 competition, 34, 36, 81, 113, 116–122, 124, 125, 254, 280 macroeconomic database, 309 MAE, 33, 34 MAPE, 33, 34

Markov switching, 337, 344, 345 outliers, 145, 154, 155 martingales, 272, 328, 330 over-dispersion, 288 MASE, 34, 116, 117, 126, 127, 306 maximum likelihood estimation, 32, parameter space, 32, 79, 163-168, 229, 75–79, 192, 193, 221, 281, 293, 295, 230, 235 301, 341, 345, Pegels taxonomy, 20 see also likelihood penalized likelihood, 35, 113, quasi, 78 see also information criteria mean absolute error, see MAE percentage errors, 33, mean absolute percentage error, see see also MAPE permanent component, 336-339, 344 mean absolute scaled error, see MASE persistence vector, 42 mean squared error, see MSE point forecasts, 12-14, 19-25, 31, 63, 89, measurement equation, 14, 42, 218, 220, 91, 94, 99, 131, 135, 136, 138, 248, 298 METS (modified ETS) model, 272, see also forecast mean Poisson distribution, 287–289, 292, 294, 274-276, 278, 279 295 minimum dimension models, 157-160, 170, 178, 223 positive data, 265–286 model classes, 84, 85, 266, 267 prediction distribution, 83, 90, 91, model selection, 35, 113-127, 203-204, 96-98, 147, 196, 273-280, 314 247-251, 302 simulated, 84-89, 135, 138 model, statistical, 13 prediction error decomposition, 192, MSE, 33 193, 203, 221 MSOE state space models, 15, 217–235 prediction intervals, 31, 91, 96-98, 135, multiple seasonality, 237–263 248, 282-283 model restrictions, 245-247 prediction validation, 124, 127 multiple sources of error, see MSOE state space models QR/upper triangular decomposition, multiplicative error models, 25, 27, 28, 30, 31, 270-277 R software, 3 multivariate exponential smoothing, 297-310 random seed state vector, 187-216 random walk, 49, 65, 66, 149, 156, 175, negative binomial distribution, 287, 190, 306–308, 327, 328, 330, 331, 289, 290 negative entropy, 115 with drift, 66, 74, 153, 330, 338, 339, nonlinear state space models, 14, 61-74, 343 reachability, 158, 159 normalization, 131-144, 159, 160, reduced form, 42, 62, 65, 155, 156, 171, 169-170 173, 176-180, 182, 184, 185, 223-228, 230, 231, 234, 245, 261-263, 300, 304-305 observability, 158, 159 observation equation, see measurement regime switching, 337, 344, 345 equation regression diagnostics, 152-155 optimization, 77, 81, 166, 235, 302 regressor variables, 145-156 starting values, 32, 75, 80, 81 reorder level, 319, 321, 322 option prices, 328 residual checks, 153-156 order-up-to level, 319, 322 RMSE, 251

root mean squared error, see RMSE safety stock, 319, 322-324 sales data, 314-318 scaled errors, 34, 126, 306, see also MASE Schwarz BIC, see BIC seasonal adjustment, 19, 131, 139, 140, 232, 233 seasonal levels model, 57, 73, 233 seasonal models/methods, see also double seasonal method, see also Holt-Winters' method, see also multiple seasonality, see also normalization fixed seasonality, 73 parsimonious, 57, 73, 243, 245, 250, 256 seasonality, 18 seemingly unrelated models, 299 simple exponential smoothing, 14, 20-22, 49, 98, 101, 117, 176, 177, 232, 270, 273, 289, 291, 315, 317, see also local level model single exponential smoothing, 21 single source of error, see innovations state space models sMAPE, 34 smooth transition autoregressive models, 337 smoothing time series, 204-205, 231-233 software, 3 SSOE state space models, see innovations state space models stability, 45, 50, 53, 55-57, 59, 63, 65, 67, 68, 74, 79, 160–163, 169, 170, 176, 180 standardized variance, 192, 194, 195, 198, 199, 201, 205, 216 STAR models, 337 start-up assumptions, see finite start-up assumption, see infinite start-up assumption state equation, see transition equation state space models, 14-15, 25-31, see also innovations state space models,

see also MSOE state space models

state vector, 14, 41, 42, 61, 62 stationarity, 45, 46, 55, 172-176, 179, 180, 189-192, 206, 222, 288, 329 stochastic lead-times, 89, 101-102 stochastic trend, 339 stochastic volatility, 334 structural models, 15, 219, 297, 305-306 sum of squared errors, 77, 192, 193, 200, see also discounted sum of squared errors symmetric mean absolute percentage error, see sMAPE

tests of Gaussianity, 154, 155 Theta method, 23, 56 threshold autoregressive models, 337 time series decomposition, 17, 19, 335 time series patterns, 11, 12 time series regression, 145-156 transition equation, 14, 42, 218, 298 transition matrix, 42, 45 transitory component, 336, 338, 339,

342-344 trend, 18, 335, 336, 339

triangular stochastic equations, 193, 194, 209-216 truncated Gaussian distribution, 266

uncertainty sources of, 83 unstable sample paths, 267

VAL method, see prediction validation VAR models, 297, 303, 304, 306-309 VARIMA models, 297, 303-306, 310 vector error-correction model, 304 vector exponential smoothing, 297-310 volatility, 328, 334

website, 3 weekly data, 57, 79, 81, 147-149, 282-284 Wiener processes, 328–330 Wiener-Kolmogorov filter, 232 Winters' method, see Holt-Winters' method Wold decomposition, 45, 46, 173, 223, 338